Minimizing the Environmental Impact of the Disposal of Snow from Urban Areas

Proceedings of Workshop June 11-12, 1984

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1985

Report EPS 2/UP/1
October 1985

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MINIMIZING THE ENVIRONMENTAL IMPACT OF THE DISPOSAL OF SNOW FROM URBAN AREAS

Proceedings of Workshop held in Montréal, Québec, June 11-12, 1984

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Report EPS 2/UP/1
October 1985

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PREFACE

The American Public Works Association and the APWA Research Foundation were pleased to assist Environment Canada in conducting the workshop from which these proceedings were derived. Snow removal and disposal is an important public works function for our members in northern areas. The location and environmental constituents associated with the disposal of the snow are important considerations for all snow disposal operations.

A spirit of cooperation and understanding of the problems faced by all levels of government is needed. Federal, provincial, and local officials must work together if a coordinated, environmentally effective program is to be developed at an affordable cost.

These proceedings set out the perceptions of local and provincial officials and researchers regarding the current knowledge of snow disposal practices. Reports of the three panels set forth desirable practices, research needs, environmental factors to be considered, what is known about the impact of current practices on the environment, site selection, monitoring practices, and principal constraints to minimize environmental impacts.

These proceedings present a strong case for the establishment of tri-level governmental working groups to address required regulations on almost a case-by-case basis. Differences between disposal facilities and environmental features vary widely, making a single set of guidelines or regulations almost impossible to develop and implement. The proceedings also point out the numerous areas where additional research appears to be needed. Such research would help to mimimize the possibility of inadvertently initiating or continuing practices which in the future may be found to have created major environmental problems.

We hope that these proceedings will assist in the development of appropriate programs to establish local guidelines for snow disposal. In addition, we urge consideration of funding the research needs which have been identified.

Richard H. Sullivan
General Manager,
APWA Research Foundation

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The APWA Research Foundation wishes to express its thanks to the many individuals who contributed their time and resources to making the workshop possible.

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INTRODUCTION

In response to public concern regarding the disposal of snow from urban areas, Environment Canada commissioned the American Public Works Association to convene a two-day workshop to explore how to minimize the environmental impact of the disposal of snow from urban areas. The workshop was held June 11-12, 1984, in Montréal, Québec. In attendance were approximately 45 persons. Twenty-four participants were local government employees, five were from provincial governments, seven were from universities, five from federal agencies and four from consulting firms. Participants were from four provinces and from Sweden.

The disposal of urban snow has gained attention as information about contamination associated with urban areas has become available. Stormwater runoff has been found to contain heavy metals and organic contaminants. Snow removal operations generally employ chemicals such as chlorides of sodium or calcium to inhibit ice formation and melt the snow, and abrasives are used extensively. Refuse in or along road rights-of-way also mixes with the snow. Recently it has been shown that contaminants in atmospheric fallout build up rapidly in snow that is not promptly removed.

Snow from urban streets has been dumped on land and in quarries and receiving waters, and into sewers to wastewater treatment facilities. Local officials charged with snow removal, licensing authorities, and the public have all expressed concern regarding the practices used and what should be done to minimize short- and long-term pollution.

Two provinces have made an initial effort to provide guidance. The Ontario Ministry of the Environment published, in August 1975, *Guidelines for Snow Disposal and Deicing Operations in Ontario.* Likewise, in December 1983, the Government of Quebec published *Lignes directrices pour l'élimination des neiges usées* (Guidelines for the Disposal of Snow).

Panels were organized during the workshop to discuss disposal of urban snow to a) land and quarries, b) receiving waters, and c) wastewater treatment plants.

To guide group discussions, eight questions were prepared for consideration by each panel:

1) What are specific environmental factors which must be considered for the location of disposal sites?
2) What is the impact of current disposal practices on the environment?
3) What is the status of current research on means to define the environmental impact and minimize environmental effects from snow disposal?

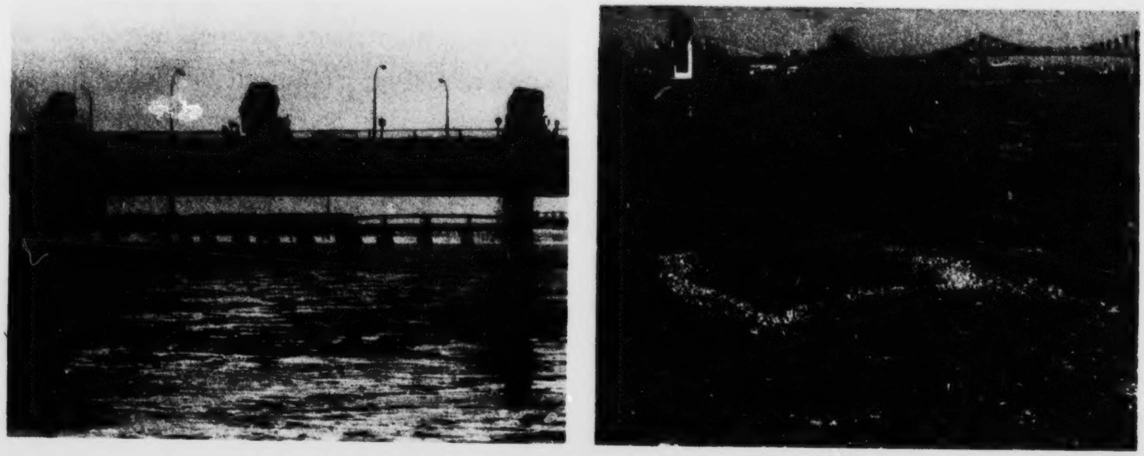
Each winter, some three million cubic metres of snow collected from the streets of Montréal are dumped into the St. Lawrence from the Concorde Bridge.

4) What monitoring practices are desirable at snow disposal sites?
5) What criteria should be used to select a disposal site?
6) What constitutes good practice of snow disposal?
7) What are the principal constraints in minimizing environmental impacts of snow disposal practices?
8) What research needs exist which are required by public agencies to improve snow disposal practices?

These proceedings comprise the reports of the three panels and various presentations, as well as a summary of the questions, statements, and responses made during discussions.

The panels identified a wide range of environmental factors which must be considered for each disposal site. Some factors were of a general nature, i.e., noise from the operation, screening of the site, and proper cleanup and eventual closeout. Other factors were very specific, such as the desirability of having the disposal site adjacent to a receiving water if snow disposal is on land, the need for impermeable soils, and height limitations when dropping snow into sewers.

The need for permanent disposal sites near the source of the snow was a common concern, as was the need to restrict use of the site to authorized haulers. For land disposal, it was considered important that alternative summer uses be possible.



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The effects of current disposal practices could not be readily categorized. It was agreed that site-specific features of each disposal operation govern the impacts, making individual site review indispensable.

The potential for heavy metal contamination of land and or receiving waters was a major concern to the panel members. Concern was expressed that all collection methods picked up urban litter and grit with the snow. The potential problems associated with the use of deicing chemicals was also a major concern, particularly their impact on land and/or receiving waters.

Little research has been directed to the snow disposal problem. A long-term effort at the University of Toronto and a study for the City of Montréal were noted. It was speculated, however, that work being performed in a variety of speciality areas by universities might be relevant. The problem may be a lack of communication between those concerned with snow disposal and the researchers.

It was agreed that among the more pressing research needs was the identification of a "marker" which could be used to indicate contamination from snowmelt in receiving waters. Uniform sampling and analytical procedures are also needed, as well as specific studies concerning the effect of trace metals on biological systems and the effect on organic contaminants of later treatment with disinfectants prior to use of the water as a potable supply. Development of alternatives to chlorides for chemical control of snow and ice should also be of high priority.

Monitoring practices for disposal sites were also suggested. Baseline studies are required to establish site conditions before the start of disposal. Receiving waters and snowmelt should be monitored for dissolved contaminants as well as solids of environmental concern. Soil at land disposal sites should be monitored for heavy metals and chloride buildup. Noise levels at the disposal site boundaries should also be monitored.

Criteria for site selection for disposal were developed as well as what could be considered "good practice".

There was considerable discussion of the role of snow removal and disposal in adding pollutants such as deicing chemicals and atmospheric contaminants to receiving waters. The latter contaminants can be expected to reach receiving waters even without snow removal. The impact of disposal during the winter when fish and other biota are at low levels of activity was compared to the impact of snowmelt from land disposal sites in the spring when biological activity is at a higher level. It was concluded that, from the standpoint of fish and other biota, less potential for damage may exist during winter-time discharge.

The overall discussion raised a number of significant issues which appear to require research. The need for facts rather than opinions was expressed.

The role of lead was given a great deal of attention. The research studies that were reported tended to show that lead was generally insoluble and that a major source was leaded gasoline. A conclusion of the participants was that the use of leaded gasoline should be discouraged. The impact of acid rainfall on the forms of lead found in the environment was also a major concern.

The workshop concluded with strong expressions by local government representatives that the development of guidelines and regulations should be accomplished by or through working committees of all levels of government. In addition, there should be sufficient flexibility to allow specific-site factors to be considered.

KEYNOTE ADDRESS

Paul Choquette
Director, Industrial Programs Branch
Environmental Protection Service
Environment Canada

On behalf of Environment Canada, and our Minister, I would like to welcome you to the workshop on Minimizing the Impact on Disposal of Snow from Urban Areas.

First, I would like to thank the American Public Works Association and the Ontario Society for Civil Engineering for helping us put this workshop together. Most of all, however, I thank you, the participant, for accepting our invitation and for your willingness to work diligently over the next two days in addressing the issues associated with urban snow disposal. The federal government has always maintained an interest in snow disposal, primarily in areas associated with acid precipitation, water quality, and the need to manage snow removal and disposal from the large number of federal facilities across Canada. The current level of activity, however, can be attributed largely to our Minister's earnest desire to develop a total and practical response to our urban snow disposal problems with municipal officials. There were many problems this past winter. It was on his return from Montréal a few days after a major snow storm this past winter that we first heard of the Minister's concern on this matter. He indicated that he was concerned with snow disposal practices and their impact on the environment, and that we were to put a plan together to remedy the situation on an urgent basis. In fact, we were almost told to develop some form or regulation within a matter of weeks in order that it could apply to the snow disposal season. This is what a minister expects from his staff. After debating internally how we would meet his desires, he looked at the options available to us and we recommended that a workshop where the real experts would participate by proving their views, experiences and wisdom, would be the ideal route to follow. I think you will concur that the expense to which the department has gone in bringing you here today is an indication of the sincerity of our interest. Indeed, it is our belief that those closest to the urban snow disposal problem are probably the most appropriate to discuss the problem. We do not profess to be experts in this area. By convening a workshop of participants and recognized experts, such as you, we think that a thorough discussion on the issues and the practical ways of addressing them will result.

By bringing you together at this time we hope that the advice this group will offer will be available to others in time for the approaching winter. I understand that you do not all have the same background and it is quite unlikely that you will all share the same point of view. The workshop has been structured in an attempt to make maximum use of those things which you have in common. In discussing the issues before you, I would ask that if total agreement is not possible, then that some consensus or meeting of the minds be reached. We are depending on you, the participants, to produce a meaningful report. You are here because of your knowledge, not your affiliation.

What are we looking for from this workshop? Basically, we have two potentially conflicting needs to address: the need to dispose of snow and the need to protect the environment. What we want, therefore, is practical advice on how to manage urban snow disposal in an environmentally sound manner. Your efforts should result in a practical guide to snow disposal.

In the material that has been provided to you is a list of those things we are asking each of the panels to consider. This list is by no means complete, but we ask that you use it as a minimum checklist. We've also taken some liberty with the original charge to the panel which is in your handout. I would like to read it with you now. First, what currently constitutes good practice for snow disposal? What is the impact of current disposal practices on the environment? What are the principal constraints in minimizing environmental impact from the means or methods used for snow removal? What are the specific environmental factors which must be considered for the location, operation and perpetual care of disposal sites? What criteria should be used to select, operate, and close out the disposal site? What is the status of current research on methods to define the environmental impact and minimize environmental effects of snow disposal? What research needs exist which are required by public agencies to improve snow disposal practices? And finally, a summary of the recommended practice.

In your consideration of land, water, and wastewater system disposal operations, I would recommend that you get into a discussion of the technical, the economical, the institutional factors as well as the more general concerns of the public in areas where the collective knowledge is sufficient. I also ask for your recommendations for research, because in addition to the publication of the discussions of this workshop, we hope to be able to push for follow-up to the research recommendations.

A PROVINCIAL VIEW - QUÉBEC

M. Ronaldo Raviolatti
Coordonnateur de projets normatifs
Ministère de l'Environnement du Québec

I was very pleased to accept the kind invitation of the American Public Works Association to participate, as a representative of the ministère de l'Environnement du Québec (Quebec department of the environment) (MENVIQ), in this workshop on the environmental impacts of waste snow disposal.

I wish to begin with a summary description of the present situation in Quebec. To that end, I will discuss the following topics: precipitation, waste snow management, environmental impacts, trends observed in Quebec, complaints, and the legal context.

In southern Quebec, annual precipitation ranges from 800 to 1400 mm, 25% to 35% of which falls in the form of snow; excluding mountainous areas, this means that annual accumulated snowfalls range from 200 to 350 cm.

Because snowfalls are so abundant, municipal governments in urban centres face significant problems in the removal and, in particular, disposal of waste snow from public roads. In rural areas and in certain urban areas where sufficient setback is allowed for buildings, snow is generally plowed or blown along roadsides wherever sufficient accumulation space is available.

In 1979, MENVIQ conducted a survey of waste snow management among the province's 383 municipalities with a population of more than 2000. Responses to questionnaires were received from 239 of these municipalities. Sixty-two percent of respondents indicated that they used 393 specific disposal sites.

The results of this survey clearly show that the most common disposal methods requiring dump sites in Quebec are direct dumping into streams and dumping on land. Dumping into sewer systems and snow melting are methods applied in only a few locations on the island of Montreal, where physical or geographical restrictions and economies of scale in terms of transportation distances can justify their use.

Furthermore, the survey provides only partial estimates of the volumes of snow transported to dump sites. Of the 147 municipalities indicating the presence of snow dumps within their boundaries, only 83 provided an estimate of the volume of snow involved, namely some 30 million cubic metres. This volume of snow is distributed as follows: 64% dumped on land, 29% in watercourses and 7% in sewer systems or snow melting systems.

Economically, the data collected in the survey were again partial in that all actual expenditures, such as depreciation on equipment and lands, are not always included in the snow removal budgets of municipalities. Conversely, according to data supplied by the ministère des Affaires municipales (Quebec department of municipal affairs), Quebec municipalities as a whole spent at least $111 295 000 on snow removal, transportation and disposal operations in 1980, a year in which total snow falls were relatively light; on the average, this amount represented 3.5% of their overall budgets.

Economic data supplied by two major Quebec cities (Montreal and Quebec City) made possible a classification of the various disposal methods in ascending order of their approximate unit operating costs.

UNIT OPERATING COSTS OF DISPOSAL METHODS
(Quebec City and Montreal)

Disposal Methods	Unit Operating Costs ($/m^3) 1978-79
Dumping into watercourses	0.04 - 0.07
Dumping into sewer systems	0.06
Dumping on land	0.23 - 0.34
Melting	0.80 - 1.58

The principal inconveniences of waste snow disposal stem from contaminants in waste snow, and from certain management and operational problems inherent to the various disposal methods.

Contaminants found in waste snow come from various reactions or operations generated by human activity. Only a portion of the contaminants emitted or deposited into the environment are mixed into waste snow and concentrated, to varying degrees, on dump sites.

Contaminants likely to affect groundwater or surface runoffs, soil and live organisms, including humans, are the following:

- melting agents: sodium chloride and calcium chloride spread on roads, which dissolve on contact with water or snow;
- lead particles (combustion of leaded fuels), which generally combine with suspended solids;

- abrasive materials (sand and fine gravel spread on roads);
- iron and zinc particles (corrosion of metal parts), which also combine with suspended solids;
- waste and debris of all sorts;
- phosphorus (anticorrosive agent combined with the salt spread in certain cities);
- oils and grease (motor vehicles and oil-fired heating systems).

In terms of quantity and as an example, Ontario and Alberta studies indicate that barely 10% to 15% of salts spread on the roads of those provinces are found in snow transported to dump sites. In Quebec, where snowfalls are greater, this percentage can be higher. It can nevertheless be stated that the majority of road salts are carried by surface runoffs into sewer systems or drainage ditches, which in turn flow into watercourses. It should be remembered that certain contaminants (lead, iron, oils, grease, dusts, and so on) are found in the streets year-round and, consequently, are carried in significant proportion, after each storm or street cleaning, into natural or artificial drainage systems that usually flow into watercourses.

A poor location, insufficient supervision or the absence of certain procedures can also lead to various nuisances, such as:

(A) Roadside Plowing:

- piling of snow can reduce, for part of the winter, the hours of sunshine received by nearby residences or other types of buildings;
- lawns and trees are slightly affected by the accumulation of snow, thereby causing late growth in the spring in some cases.

(B) Dumping into Watercourses:

- risk of creating ice jams and floods;
- risk of shoreline erosion at point of dumping;
- necessity of encroaching into watercourses in some cases;
- pollution of watercourses as well as their beds and shores, and subsequent difficulty of cleaning them up.

(C) Dumping into Sewer Systems or Melting:

- risk of blocking sewers or breaking sewer pipes;
- introduction of large volumes of parasite water in the case of sanitary or combined sewers;

- pollution of watercourses where no intermediate treatment system exists.

(D) **Dumping on Land:**

- unesthetic and unhealthy appearance: blackish crust and land littered with waste and various debris;
- risk of flooding adjacent lands in the event of poor drainage during the snowmelt period;
- possibility of unpleasant smells in the spring;
- possibility of creating a microclimate (local fog) during the spring snowmelt.

(E) **All Disposal Methods:**

- noise from heavy vehicle traffic and unloading;
- possible depreciation of adjacent lands if the disposal site is located in a residential area.

The pressure generally exercised by construction projects on the urban fabric currently tends to restrict or even cause the disappearance of lands until now reserved for snow disposal. Often, the relocation of a snow dump leads to increased transportation costs because longer distances must be travelled to and from the districts from which snow is removed.

In addition, because of municipal budget restrictions, some municipalities would apparently prefer less costly but more environmentally harmful disposal methods, such as dumping into watercourses, in comparison with dumping on land.

Finally, in a number of municipal districts, new developments are not always planned to take into account the roadside plowing of snow. In other areas, residents call for snow to be removed to a dump site, even if they have the required accumulation space in front of their property, because they no longer wish to suffer the minor and temporary inconveniences resulting from the presence of plowed snow along the curb.

In recent years, MENVIQ has received several complaints and petitions each winter on the subject of snow removal. These have dealt either with water pollution (salt, lead, sediments, wastes), in the case of snow dumping into watercourses, or with other problems such as noise, health and flooding of adjacent lands, primarily in reference to the operation of dumps on land.

It should be noted, however, that only part of the complaints related to this type of activity find their way to MENVIQ because citizens generally first try to solve their problem by addressing municipal government; the public turns to MENVIQ only as a second resort. In most cases, MENVIQ's action consists of opening a file, conducting inspections and holding meetings, collecting snow samples if necessary, and forwarding opinions or recommendations to the interested parties.

Legally, MENVIQ can take action under sections 20 and 25 of the Environmental Quality Act, when it is able to demonstrate that the emission, deposit, release or discharge of a contaminant mixed with snow can endanger the life, health, safety, welfare or comfort of human beings, cause damage or otherwise prejudice the quality of soil, vegetation, wildlife or property. The Deputy Minister may then order whoever is responsible for the source of contamination to stop finally or temporarily, or to limit, in accordance with the conditions imposed, the emission, deposition, release or discharge of the contaminant.

Since the adoption of the Environmental Quality Act in 1972, the disposal of waste snow has been the subject of periodic study and discussion within MENVIQ. Until recently, however, no official position had been stated. In the absence of environmental directives, municipal officials responsible for waste snow management selected their disposal sites and methods primarily on the basis of economic considerations. For this reason, MENVIQ recently made public a series of guidelines for the disposal of waste snow; this will ensure that environmental considerations are given the same importance as economic considerations in waste snow management decision-making.

Since the creation of the Quebec water pollution control program, MENVIQ has worked with municipalities to clean up major sources of pollution in the province's lakes and rivers. The considerable effort which the various interested parties have agreed to expend to return watercourses to their former quality and uses must be supported by equivalent action in the less polluting, but nonetheless problem area, of waste snow management. This new policy, therefore, complements the water pollution control program. This program necessitates considerable investment and focuses simultaneously on all sources of pollution.

The primary objective of the MENVIQ policy is to prevent or minimize impacts on and inconveniences to man and his environment resulting from the disposal of waste snow. Such inconveniences as described previously fall into two categories: those related to the presence of contaminants, and those related to disposal operations and their location (damage to trees and lawns, erosion and flood risks, breakage of sewer lines, noise and other problems caused by a significant increase in truck and other heavy equipment traffic).

To achieve this objective, MENVIQ plans to encourage use of certain disposal methods because of their smaller impact on natural and human environments. This policy also favours the recovery of watercourse uses, in accordance with the targeted objectives of the Quebec water pollution control program.

From the recently announced guidelines, MENVIQ is writing a directive to clarify existing orientations and establish criteria on the location, management and operation of various known methods of snow disposal. Anticipated standards and criteria will be submitted to the various interested parties for consultation; these parties will have six months to address their comments to MENVIQ. Subsequently, an official version of the directives will be published.

MENVIQ feels that preference should be given, wherever possible, to roadside plowing, which involves the least possible amount of handling and creates no major concentration of snow and possible contaminants at given site.

If a disposal site proves essential to serve certain districts, the method of disposal, management of the site and inherent operations should meet certain conditions to provide major natural systems (water, air, soil and living organisms, including humans) with good protection. For specific dump sites, MENVIQ recommends disposal methods that make possible retention or treatment of the greatest possible quantity of solid contaminants at the dump site or before the discharge point of snowmelt waters.

The levels of certain contaminants in snow can also be controlled at source insofar as municipalities ensure a rational and regular control over the practice of spreading abrasives and melting agents. Municipalities could also further encourage their citizens to cooperate more closely with municipal services so as to ensure that household garbage, on garbage collection days, is not mixed in with snow to be removed from streets and roads for disposal.

Here then, in order of environmental preference, are the various diposal methods:

(A) **Preferred Methods:**

- roadside plowing;
- dumping on land;
- snow melting.

(B) **Methods Acceptable for Exceptional Cases and Only After a Thorough Study of Each Specific Situation:**

- dumping into sewers (combined);

- dumping into watercourses.

As the first method of disposal, MENVIQ encourages municipalities to plow snow onto roadsides wherever feasible. This method is the least harmful to the environment because it makes possible the even distribution of contaminants in time (spring snowmelt) and in space (along roadsides). This method offers other undeniable advantages, such as:

- low transportation and energy costs;
- no cost for managing and operating a dump site;
- few local nuisances.

When snow cannot be plowed along the roadside and must be transported to a snow dump, such a dump should meet a minimum number of location, management and operation standards. Here are certain considerations which may apply to various disposal methods:

- site preferably located in an industrial zone or at an appropriate distance (depending on whether natural or artificial screens are present) from existing or planned residential buildings;
- site comprising adequate and safe facilities for long-term use.

The dumping method preferred by MENVIQ is dumping on land in accordance with certain conditions, namely:

- minimum distance from any source or body of water;
- soil or surface making it possible to limit groundwater contamination risk;
- topography favouring rapid and adequate spring snowmelt;
- appropriate drainage to limit flood risks for adjacent lands;
- appropriate facilities for sedimentation of suspended particles and removal of floating substances;
- discharge of treated snowmelt waters at a point creating no harmful impact on the environment;
- leveling and working of dumped snow in the spring, and cleaning up of land after snowmelt for health and esthetic reasons;
- sites with year-round limited access and uses.

In old or highly developed cities, where suitable land for snow dumps is rare and the distances and costs involved in transporting snow to suburban dump sites are quite high, use of another disposal method may be considered. Thermal melting equipment may prove a solution when the investment and operating expenses of this method are both economically and environmentally justifiable.

The major points to consider regarding the facilities required to operate melting equipment are as follows:

- equipment should favour sedimentation of suspended solids and removal of floating substances;
- treated snowmelt waters should be discharged at a point which creates no harmful impact on the environment;
- winter and spring cleaning of melting ponds;
- limited site access.

Direct dumping of solid snow into storm drains is difficult in winter and not recommended because of the low rate of flow normally found in storm drains at this time of year. Snow cannot be dumped into sanitary sewers because such drains are generally too small in diameter (less than two metres) and because snow contributions run counter to treatment technology, which seeks to avoid dilution of sewage by surface runoffs in order to facilitate concentrated sewage treatment in plants.

As a general rule, snow can be dumped directly into combined sewers only in limited amounts, and only in a few major urban centres because of the need to use large sewer pipes with specific flow characteristics. This solution may be considered when other methods of disposal provide unfeasible, cause greater damage to the environment and are more costly. It is acceptable in exceptional cases, provided that snowmelt waters transmitted to watercourses have been treated and that such waters do not reduce wastewater treatment effectiveness.

The principal conditions to be met for dumping into combined sewers are the following:

- collectors and interceptors considered for use must be able to absorb irregular contributions of snow while minimizing risks of blockage and additional sewer pipe cleaning costs;

- present and planned sewer dumping points must comply with the Quebec water pollution control program.

Although it is the least expensive snow disposal method, direct dumping into watercourses is also the least acceptable from an environmental standpoint. Because all contaminants are dumped untreated into watercourses, water quality may be affected as well as aquatic fauna and flora, and there is little likelihood of recovering contaminants carried off by the current.

Dumping into watercourses therefore must be limited to exceptional cases where other disposal methods have been ruled out because of excessive physical, technical or economic constraints. MENVIQ will develop an action plan to gradually reduce dumping into watercourses from present levels in accordance with the Quebec water pollution control and wastewater treatment plant programs.

The following important elements should be considered before establishing any exceptional site for direct dumping of snow into watercourses:

- at the point of dumping, snow must fall directly and completely into a watecourse whose surface remains unfrozen during the entire winter;
- a minimum rate of flow and adequate depth are required to avoid shoreline and streambed erosion and to favour proper dispersal of each mass of snow carried by the current;
- each dumping point must be studied by the proponent to avoid any risk of ice jams and contamination of drinking water intakes, and to demonstrate that the aquatic environment will suffer no marked effects;
- the site must be of limited access to avoid dumping of residue or waste other than snow.

In closing, I want to remind you that MENVIQ has no intention of legislating snow diposal activities. We are instead relying on the cooperation of all parties concerned, in particular municipalities, to see to it that future published directives are applied so as to ensure more adequate protection of the environment.

MENVIQ also feels that, given the changing status of urban lands, snow management should become a subject of continuing concern for municipalities. This attitude would make possible improved land use planning, and environmental management that takes into account snow removal and disposal problems.

A PROVINCIAL VIEW - ONTARIO

Marcia Weaver, Environmental Planner
Ontario Ministry of Transportation and Communication
Province of Ontario, Canada

I intend to present a very general and brief overview of our Ministry's point of view. At this time, we do not really have a formal, written policy on snow disposal procedures. The appropriate direction for such a policy requires more clarification of the issues. I hope to obtain some insights from this workshop and take those of importance back to Toronto.

To provide you with some background, our snow disposal-removal from the site is primarily in urban areas, mostly in the Toronto area, the golden horseshoe area, the north shore of Lake Ontario, and the major urban centres. There is some in the rural areas but only in very localized spots where the accumulated snow infringes upon the pavement. We have relatively low snow accumulation because we use salt; however, in the last 10 years, according to our maintenance staff, the amount of snow removed has really decreased. We have had fairly mild winters in Ontario and we have increased the width of the rights-of-way that we obtain. Thus, we have a fair amount of roadside storage area for snow in most urban areas. We have had some increases in the need for snow disposal because we have had a program of constructing noise barriers. Snow does tend to pile up on the freeway along the sides of these. Presently, we remove snow where it obstructs traffic. The main areas from which snow is removed are those areas which do not have sufficient shoulder area for storage, such as freeways with no shoulder areas; bridges (one that you might all be familiar with is the skyway between Burlington and Hamilton); overpasses and underpasses; retaining walls; guide rails; and as I mentioned, noise barriers.

Where the area is large, we use front-end loaders to remove the snow; and shovels are used in more localized areas such as small bridges. As for disposal, often in the cases of bridges and in urban areas, we just push it off to the end of the structure and the snow melts on the right-of-way. This becomes in a way a mini-disposal site. Melt will flow into the lowland and into the receiving waters. Sometimes when there is a large accumulation or when we have several small sites in an urban area like Toronto or Hamilton, we will take it to a ministry control yard where we have salt storage facilities and garages where we usually have a little extra property. Snow is taken to yards which are fairly accessible to the source. In some cases, yards are near a watercourse and in some cases they aren't. There are places, for instance in Ottawa, where we use municipal snow dumps for which we have received permission to use. The municipality also uses the snow dump site. From what I understand, there are no certificates of approval or any formalized procedures, rather, it is just an agreed-upon area where snow is dumped. Currently, and for quite some time, we have not had any direct disposal into receiving waters.

Briefly, the legislation and policy in Ontario which covers this snow disposal in terms of our concern is the Environmental Protection Act, which, of course, prohibits contamination. Contamination is basically defined by the Water Quality Objectives of the Ministry of the Environment, and the Ministry has a policy which was published in the form of a policy guideline which has been supplied to all participants. The policy is very simply stated: there is to be no direct snow dumping into or onto any frozen water body without approval from the Ministry of the Environment. Our working policy conforms to this policy.

As I mentioned before, the Ministry of the Environment published guidelines on snow disposal in 1975. I will briefly outline them now. The first guideline is that the quick removal of snow is encouraged. Many studies have shown that the longer snow sits on the roadside, the more time it has to accumulate contaminants. If snow is removed quickly, studies in some cases have shown that sodium and chloride, for instance, are much lower in fresh snow that they would be in a salt runoff situation. If that can be accomplished it is definitely a recommended procedure. Snow and garbage should also be separated. Picking out trash from snowpiles is very inefficient.

Disposal of snow on an approved land site is the preferred choice. This is distinguished from a sanitary landfill site of a municipality. The intention here is to separate the snow and the garbage. We do not want snow to aggravate the leachate situation at a sanitary landfill site.

In terms of siting considerations, which is probably the most important issue, the province recommends that we consider access; also we must be practical, we cannot be carrying snow all across the province.

Noise consideration is important because equipment used is very noisy and oftentimes there are residents in the area. Noise can be a real infringement on their privacy. The future use of the site must also be considered. As we know from research, the soil becomes a treatment site if a land site is used for long. The soil will become very high in lead, sodium, and all sorts of other contaminants. So if the site is to be used in the future, particularly for residential development, we must consider future use. Visual considerations are also important. The snow piles up and can be quite unsightly.

Hopefully the surrounding topography can be used to camouflage it if possible, or major residential areas can be avoided area. Drainage to surface and groundwater is another important consideration. The idea is to maximize the distance from surface water. Of course, there is special sensitivity for cold water fisheries or low flow, or if there is a water intake downstream. Groundwater may be of concern mostly because of sodium chloride. The quality of water for downgrade well users must be considered. They should not receive the contaminants; contaminants should not leave the site. Soil stabilization is important because there may be much erosion when melting begins. Public safety is also a concern because sites sometimes are a favorite playground area for children. Again, I make the point that municipal sanitary landfill sites should not be used for obvious reasons. Snow disposal sites that are used by local agencies or contractors should be inspected weekly by the local authority.

We have reviewed some of the literature available and based on what I have seen there are many areas of concern that are not covered by the guidelines of the Ministry of the Environment.

In summary it seems like the main concerns centre on protection of surface waters and wetlands. There is concern for drinking water and stream biota in terms of particulates. It seems to be fairly general knowledge that a lot of the particulates remain at the site and are captured by the soils. However, some do leave the site and are deposited on the stream bed. There seems to be a feeling that the soluble portion of lead is not a problem in the short term; perhaps longer-term studies are needed to substantiate that, to make certain that lead does not become biologically available. Sodium chloride, of course, is a problem. Chloride particularly is extremely mobile. Sodium, again, may be held up at the site or held up in the stream bed materials. As I mentioned before, if snow is taken directly or regularly from the site, you can cut down on the total sodium chloride deposited there. Studies have shown that in some cases the sodium chloride in fresh snow is very low. However, chloride accumulates at the site and upon thawing, can create a problem. A study was done by William Scott in Ontario on the Black Creek. Scott did not look at snow disposal sites; rather he looked at a situation where snow had accumulated on the roadside for the whole winter or up until January; then a sudden thaw took place all at once. For a few days he found up to a fifty-fold increase over ambient sodium chloride. Other studies have shown that peak loads can be in the order of three times the ambient. This is an indication that there could be a substantial problem.

Suspended and dissolved salts, of course, are likely to be high. Dissolved salts will be mostly chloride and probably sulphates. Suspended salts could be a variety of things including salts from the site. Most of the sites that I have looked at indicate that biological oxygen demand is not really much of a problem. A few studies have indicated that COD may be of concern and there is a possibility of the carbons being a problem. We need to look at this area more carefully. This is something that probably hasn't been looked at very much--how do the hydrocarbons work and what is their role in snow and potential contamination? There is also the problem of oil and grease. Again studies show varied results. Some have suggested that oil and grease will stay at the site for some time before being released. Often oil and grease get into the receiving waters, and of course, the problem of acid rain probably requires more discussion and study.

In terms of potential litigation, the best protection is to consider all of these problems before you choose your disposal site. Select sites away from sensitive streams, low streams, and areas where there is a drinking water intake downstream. Try to maximize your distance from the receiving waters and give the site a chance to be your treatment site. When berming and diking, use check dams which can capture some of the particulates; that would include the leads and the other heavy metals, as well as some of the solids. This can be done after the site is in place. Again, for siting consideration, clay and organic soil sites probably are preferable just because of the heavy ion exchange capacity in terms of groundwater. The main concerns mentioned in the literature seem to be sodium and chloride. These are concerns where water is being used locally, as well as for the resource in general. Again, locate the site away from areas where groundwater is used and where there is a high water table, and where there is a particularly permeable geological strata. If you don't have any choice, you may consider things like clay liners under the sites. In terms of soil concerns, we are looking at soil as sort of a sponge, but it is a resource as well, and if that soil is ever to be used for agriculture or vegetation, natural vegetation growth, or any other kind of land use, you must consider the lead in the surface soils, and other heavy metals and sodium. Chloride will probably move from the site. Oil and grease, and the fact that the area will undergo a lot of erosion and compaction from the equipment, are of particular concern. You may consider using the site permanently to avoid litigation, or when the time comes to use the site for something else, remove and replace the soils. In terms of the effects of contaminants upon agriculture and vegetation, I think it is very well known that sodium in soil can alter the physical and ionic properties and also the soil moisture relationships. It can put vegetation under some moisture stress and many of the agriculatural crops show an affinity for lead. Some studies show that metals do stay in the root part of plants, but we do not know how long it would take for them to translocate.

One general recommendation that we may consider is to just concentrate on minimizing the number of sites that are going to be used. Others might be to survey the sites that are being used now to see whether there are certain things that could be done to them to minimize impacts; decide if they should be retired at this time, if they are going to be developed soon; and monitor existing sites.

If we don't really know how significant some of these concerns are, perhaps we should be looking at the sites which seem to be sensitive and begin a regular program of monitoring salt and water quality to show what the appropriate thing is to do. Perhaps we should consider registering sites formally so that we know what they have been used for and so that a record is kept of their prior use.

SNOW DISPOSAL IN METROPOLITAN TORONTO

Tom Johnston, P.Eng., Chief Maintenance Engineer
Roads and Traffic Department, Metropolitan Toronto

The Metropolitan Toronto Roads and Traffic Department is responsible for the system of arterial roads within Metropolitan Toronto. Sharing of responsibilities under Metropolitan government leaves local roads designated "residential" and "collector" under the jurisdiction of the six member municipalities of Metropolitan Toronto.

The Metro road system totals 720 kilometres or 3200 lane kilometres. The 24-hour average daily traffic volume on our roads in most cases exceeds 20 000 and often exceeds 30 000. The volumes dictate bare pavement during rush hours. At other times, particularly weekends and late at night, we let snowfall accumulate to plowing depths in the interest of salt conservation.

In a typical winter we have a snowfall of 140 cm which includes two or three major storms with accumulations of 15 cm or more. In this typical winter we spread 65 000 tonnes of salt.

Salting

Considerable care is taken in the design and operation of our salting strategies to avoid misuse of salt. Salt is accommodated in "dome" structures in our district depots to prevent leaching. All salt spreaders are ground rate controlled to ensure accurate metering of the salt. Salt beats are designed to match the capacity of the spreader trucks assigned to them so that it is quickly apparent if equipment requires recalibration. No salt is spread until pavement surfaces become slippery. Our most successful salt conservation tactic is to discontinue salting and emphasize plowing at off-peak times.

Prior to 1970 we endeavored to provide bare pavements at all times. Our decision to lower the level of service at off-peak times as well as other conservation tactics, including the above mentioned, have resulted in a substantial decrease in salt consumption.

Snow Removal

Snow is removed from about 500 kilometres of our system when warranted by conditions. The decision to remove snow is dictated by the capacity of roadside storage for windrows. Most suburban roads have boulevards that can accommodate larger windrows than those roads in the downtown without boulevards where the windrow must be located in the curb and gutter area.

Later in the winter when the prospect of a major storm diminishes and the likelihood of higher ambient temperature increases, snow is allowed to store as long as it doesn't interfere with the safe movement of vehicles and pedestrians.

In a typical winter 500 000 tonnes of snow are removed from our roads after major storms. Before 1972, 20 percent of the snow removed was directly dumped into Toronto harbour. Environmental concerns caused us to cease direct dumping into the harbour. This coincided with a gradual loss of land disposal sites that we were experiencing. In 1969, we had 20 land disposal sites and the number has since decreased to 10.

Snow Melting

The loss of land sites and the discontinuance of harbour dumping caused us to place more emphasis on melting. We had started testing the feasibility of using mobile snow melters in the mid 1960's and in 1974 we took delivery of the first Metromelt 150 self-propelled and self-loading mobile snow melter.

We now have five Metromelts and they account for the disposal of 300 000 tonnes of snow or 60 percent of the total snow removed.

The rest of the snow is removed by trucks to land disposal sites. Disposing of snow by melting becomes cheaper than loading and trucking to disposal sites when the haul distance exceeds 5 kilometres. Our increased reliance on melters is explained by the loss of vacant land for dumping and the resulting longer haul distances to the remaining dumps.

Contaminants in Snow

Snow stored at the road side accumulates a number of contaminants such as organic material; dissolved salts, notably chlorides; heavy metals such as lead; particulate matter such as sand and clay; litter; and often domestic garbage. The level of contamination increases with time so that removing snow promptly minimizes the amount of contamination it contains.

We have found it necessary to schedule snow removal behind garbage pick-up to minimize picking up garbage, trash, and other refuse with snow.

Disposal Sites

Vacant property that completely qualifies as a snow disposal site is a rarity in a large urban centre. Since snow dumping is noisy and takes place during the night few residential areas are appropriate.

The snow dump has to be serviced with a road having capacity for a large number of heavy trucks. We may have 50 trucks hauling to one location and the access road must be able to accommodate not only the loading but the truck volume to ensure free flow of traffic.

We select sites, where possible, remote from watercourses to prevent direct surface runoff from the stockpile to the watercourse. We have one location where this isn't possible and in this case we have constructed a dike to contain the meltwater.

Despite our efforts to avoid picking up domestic garbage and refuse, large amounts of litter are included with the snow removal and end up at the disposal site with the snow. We collect and dispose of this litter progressively as the snow melts in the spring.

We recognize that the contaminant loading of the soil in land disposal sites may reach the point where the contaminated soil layer might have to be stripped and properly disposed of, although this has not yet become necessary.

Contaminants in Snow Melters

The Metromelt has capacity for storage of 8 cubic metres of dirt, debris and other contaminants contained in the snow and this capacity is adequate for an eight-hour shift. The dirt is flushed out of clean-out doors with a high pressure hose and eventually transported to land fill sites. Of the various pollutants contained in snow the only significant one that goes into solution is sodium chloride and we understand from Ontario Ministry of the Environment studies that the contribution to lake chloride levels from deicing chemicals is not critical.

What is of concern are the various heavy metals, such as lead and phosphorus, and other products of automobile emissions washed out of the air by snow. We know that, since these do not go into solution but are solids in suspension, many contaminants precipitate out of the meltwater and are removed from the melting chamber with the dirt. Floating materials are trapped since the chamber outlet is submerged. Additional precipitation occurs in catch basin dumps which we pump clean on a strict schedule.

Conclusion

Administrations responsible for winter maintenance of arterial roads and expressways are, of necessity, using sodium chloride as a deicing chemical and disposing of snow containing certain levels of contaminants. The detrimental levels of salt are not exceedingly harmful, particularly when it is remembered that its use undoubtedly saves lives. However, there is no disputing that these detrimental effects exist and they must be minimized by avoiding excessive application and misdirected spreading.

Likewise, contaminants in snow produce a potential risk of environmental pollution and snow disposal techniques must be selected that minimize the environmental impact of snow collection and disposal practices.

THE RESEARCHER'S VIEW

Professor P.H. Jones
University of Toronto

It has been five to six years since we took the initiative at the University of Toronto in the area of snow disposal. Acutally, the Institute for Environmental Studies took the lead in the concern about the environmental impact of snow and ice control. We quickly gained the support of the Association of Municipalities of Ontario which, in turn, induced a number of municipal technical officials to cooperate and caused them to come to workshops at the University of Toronto. We have been holding such workshops twice a year. I tend to call them our show-and-tell experience. It is probably for this reason that I am here because it is during these five or six years that I have learned everything I know, which is very limited. I have learned what I know from you people sitting out there.

From a researcher's point of view, there are clearly a number of alternatives when it snows. You may leave the snow exactly where it is, which I think is a policy adopted by a number of municipalities in Ontario, because by July it will probably be gone. God put it there, God can take it away. You may also move it off the traveled portion of the road and then if you do that, you have two choices which have been mentioned. That is, you may pile it on the side of the road until July, or you can carry it away and place it somewhere else. Most of the public authorities, fortunately, do not accept the first alternative of leaving it right there on the side of the road. So that leaves moving it off the traveled pavement. At that time, of course, it is usually mixed with some kind of abrasive or chemical. This then is the problem with the snow disposal activity. If you follow the second alternative of removing it from the shoulders or the sidewalks, once again you have two alternatives which have been discussed very briefly. You can throw it right in the river or the lake or you can pile it on one or more selected land sites. And, of course, this will melt in due course and run off or soak in. So this is a scenario that a researcher has to look at to determine what could be the serious problems and what could be the less serious problems.

I think the last solution of putting it on the land now is becoming far more acceptable, and it does get the snow into far more convenient locations. It permits the retention of some of the contaminants which have accumulated in the snow during the salting, sanding, and chemical additions.

A specific environmental factor that has been mentioned is noise. Equipment is a very significant source of noise and environmental contamination can be sound as well as a chemical. The pollution of the ground or surface water consists of a variety of elements which I believe you will have described to you more thoroughly tomorrow by Dr. Landsberger who has done some very careful analyses. I am certain that you are fully aware of the principal components, which would be sodium and chloride or calcium with a very nice helping of lead, particularly in the urban centres, on the freeways, and the expressways. There is also a fraction of soluble lead in there which, even though it is a very small amount, is there nevertheless.

A number of places also use abrasives so in this context you would have a considerable amount of sand. A fair amount of garbage gets mixed in, which gives you organic contamination and some suspended solids as well. The matter of treating this kind of material is difficult. Trying to treat water to remove sodium and chloride is going to be very difficult. There are several other things that you can remove but the sodium and chloride, I'm sure, are going to cause some problems.

One of the particular environmental factors that researchers are concerned about is the effect of all these substances upon aquatic life, fish, and on the biota which provides the food for fish, as well as vegetation. If you leave snow on the side of the road and there are very high concentrations of sodium chloride, you are going to have seriously damaged vegetation. We have all seen this kind of thing on the sides of highways and roads where trees, which are particularly sensitive to salt, have died.

The effects of solids is perhaps a little less obvious. Some of the solids will go down onto what we call the feeding grounds of the fish where the invertebrates grow. Now if you bind this immediately with any kind of a clay solid or something like that, where you bind the entire surface, the feeding ground is essentially destroyed.

The impact of present disposal practices on the environment are broad. It is quite clear from the early speakers this morning that Metropolitan Toronto has a different set of problems than does the Highway Authority of Montréal or Ottawa. They all have somewhat different problems. If you push snow to the side of the road and allow it to melt gradually, storm sewers will be carrying something in excess of 200 milligrams per litre of chloride, which makes it somewhat similar to wastewater and sewage in some respects. I reviewed one study which indicated that in 100 days there were something like three million kilograms of chloride deposited into a river. Now that's enough for a lot of fish 'n chips.

I have some ranges of numbers here which I'm not sure are terribly relevant except to attract your attention. BOD_5 (five-day biochemical oxygen demand) can be anything from 10 to 50 to 75 milligrams per litre. In fact, some municipalities produce

BOD waste of about 75 mg/L so you can see you're getting pretty close to snow dump material. Natural snow is much lower than that, 0 to 3 mg/L. Chloride in natural water or natural snow is something less than 10 mg/L. But in the dumped snow it can be from 100 to 9 000 mg/L, a very wide range. Oil and grease, of course, gets into the system and then gets washed off with each snowfall and accumulates with it and can reach up to 20 mg/L which is quite significant.

The contaminant most people have studiously ignored through the years is sodium. I do not pretend that sodium is the new poison of the week, I think dioxin still holds that position. I haven't read that sodium is this week's poison of the week, but sodium surely has some deleterious effects if it gets into drinking water. Sodium concentrations that have been turning up in some of the research information that I've seen are as high as 2 000 mg/L. As salt applications are reduced there is less sodium. Levels of 1 000 mg/L from secondary roads and 400 mg/L on residential streets have been reported.

Suspended solids are up there - 2 500 mg/L in the snow dumps. So you can see by collecting the snow and moving it into one location you are concentrating the problem to some extent and, of course, the only way to control a problem is to concentrate it and then apply your control at that point. You can't solve the problem spread out over the countryside.

To the best of my knowledge, there is very little pure research on snow disposal being conducted currently, although I am quite certain that it is being conducted in various compartments of the research community which, as you probably realize, do not communicate very well with each other. So apart from some of the cities and major authorities that are having particular problems, which are site-specific, I'm not aware of any research of a fundamental nature going on.

With reference to monitoring practices, clearly we are going to have to be concerned with dilution. We need to know what the water flow is in the body of water that we are going to ultimately discharge to, recognizing that perhaps we won't discharge directly to it but will discharge onto land which ultimately will discharge either to a groundwater resource or to a flowing body of water or a lake. In any case, we need to know what kind of flows to expect versus what kind of temperatures so we will be able to predict the rate at which material will reach the aquatic environment and whether appropriate dilution factors will be achieved. We also would like to know and monitor the upstream water quality if we are dealing with a flowing stream. In this manner, you may keep your name out of the paper by demonstrating that you really did not affect the stream's quality very much as it was already in that condition when it reached your site. Besides the obvious parameters which have been previously discussed, monitoring the flora and fauna of the natural situation should occur before you start dumping your snow at a particular location. Whatever already lives there, whether in the water or on the land, you need to have background knowledge so that, in fact, you can measure the effect by using flora and fauna, and vegetation on the site if you're talking about land, as parameters. Contaminants are going to affect vegetation and other living organisms.

Another thing to look at, of course, is traffic routing so that you can get some handle on the noise level. People will sometimes perceive noise where it was before only because they know that something new is happening, like dumping snow in a certain location, and they have a justification for complaint. The criterion is to select a dump site with gentle slopes and removed from residential areas. Snow should not be piled too high or it still will be there in August. We do not want to create glaciers. If there is any sand it is going to concentrate on the surface and you may very well reduce the solar radiation necessary for melting. The contaminants will provide insulation.

It would be rather nice to have a fairly impermeable surface beneath the snow dump site because this would be relatively easy to clean up in the summer and it would also prevent a lot of the material moving down into the groundwater where it doesn't move away quickly. We all know about leachate from landfill sites, so we are now more familiar with the very, very slow rate of flow of groundwater in many areas. If you have a fairly impermeable surface you could expect most of the materials to go off directly into the surface water and not pollute the groundwater.

You should be fairly close to a large river or a lake for dilution purposes and, of course, it should be fenced in for safety and preferably out of sight. This set of criteria always reminds me a little bit of the set of criteria somebody once proposed for wastewater treatment plants. They should be inexpensive and 100 percent reliable and preferably make a profit for the municipality.

There are so many parameters here that I'm sure we cannot possibly meet all of them. Sites should not be adjacent to a game or commercial fishing areas or to spawning grounds. We should be conscious that certain parts of the larger lakes do have spawning grounds that are typical for certain species of fish and one should try and avoid putting your snow dump right on the edge of the water or even some distance from the edge of the water at such locations.

One important thing perhaps which hasn't been mentioned yet is that the site should be exposed to sunshine and not shaded over by trees. The site should not be above an aquifer that is used for drinking water because clearly the water, one way or another and given time, will reach the aquifer. By the same token, the site should not be upstream or adjacent to a potable water intake for a lake or a river.

When we consider what consitutes good practice, I have a very mixed set of thoughts. I always remember when we started our workshop at the university. We brought together 25 municipal officials and each one firmly attempted to convince us that what constitutes a good practice was what they did. What the other guy did, however, did not constitute good practice. They were very nice about it. We all became very good friends. But it's a little bit like political parties; if you put 20 specialists together, you're going to get 25 different viewpoints. I suspect what constitutes good practice is going to be very much a perceived solution.

I'm going to make a suggestion because I'm the last one on the panel. I suggest that we try to dump our snow on land in large areas to insure that we get a complete melt in the summer. We are talking about disposal sites. I suspect that the best solution is to leave snow where it is, pile it up off the traveled way and leave it there, where it is appropriate and if you have the room. This is what the City of Toronto does, only they don't pile it up, they just leave it on the road. I think that was my option A, just leave it there and God will deal with it in due course. However, if we provide an area of land, we can retain particulates. We can retain the lead which is largely in particulates. We can retain any sand or abrasives. We can retain debris until the snow is melted and we are in a position to clean it up. Of course, it is a good idea, and I think it's generally agreed, not to dump directly into receiving waters because of the residue that will immediately be mixed into the system.

Now what are the principal constraints for establishing a good site? The major constraint is, I guess, that there is no control over the contaminants you are dealing with. Even if you don't remove and dump the snow in some particular location, the contaminants will still reach the ground or surface water, given time. The rate of melting, of course, is not a controllable factor and dumping provides a point source for concentrating the effect of the contaminants. So these are my ideas of the principal constraints.

Now the research needs. Well, I do not think anybody has talked particularly about the subsurface behaviour of sodium and chlorides, which are the most prevalent contaminants involved. There have been many studies that have indicated that less than 50 percent of the salt applied to a watershed can be accounted for. We did a little study at the University of Toronto, but there are many more in the United States where they have accounted for from 40 to 70 percent of the applied chemicals in the material balance sense. Now what that is telling you is that somewhere in the system there is a lot of salt bound up. It has to be. Salt either comes out in the groundwater or it comes out in the surface water. It certainly doesn't stay there. We all know that sodium chloride is a highly soluble material and so one would immediately assume that it will dissolve and go pouring out of the system. So if you put a pound on, you should be able to measure a pound off in its various locations. I wish this were the case, but in fact there are many research studies, full scale studies, which account for less than half. The little study that we did at Toronto suggested that as much as 25 000 tonnes (metric tonnes) is being stored somewhere in the system annually. It isn't getting out of the system.

Now this is a bit worrisome because there is the question of getting it out, let's say back into the sea or the oceans where it all belongs. If it is being applied but it is not getting out into the rivers or streams and it is being hung up somewhere, I sort of visualize something like the domestic softener on a giant scale were you put your hard water through the softener and you get soft water out of the bottom of it for a long time. However, one day you put your hard water in the top and suddenly you get your hard water out of the bottom and, in this case, perhaps even more. The water may then start to release the sodium chloride or the sodium perhaps, and the chloride is hung up in there. Now I really don't have any particular proposition as to how this may be the case; the storage and migration mechanism is so poorly understood. The initial concentration of this material is certainly by evapotranspiration. Subsequently, migration through the unsaturated zone of the soil into the water table may be operating at one metre per year or even less. Therefore, there is a large time separation between cause and effect. This is always an environmental problem where you can never quite link the effect to what caused it in the first place.

Sodium, if it is in very high concentration as with the domestic water softener, will replace calcium. That's how you recharge your water softener. Pouring a brine solution through the sodium kicks the calcium off and you end up with a sodium zeolite water softener. Then you put it back into the house or back in service. The hard water comes through and then calcium replaces the sodium, kicking the sodium off. I suspect something of this kind might just be happening out there in the ground. There is, therefore, an exchange capacity which can be exhausted and this a very serious area that has not been looked at very thoroughly.

Salt does other things. It reduces the activity of soil microorganisms. These soil microorganisms are important because they maintain the ecological balance in the soils and the vegetation of the whole living surface of the earth. Other research that needs careful looking at is the search for some alternative chemicals. Calcium magnesium acetate, otherwise known as CMA, is being studied right now, particularly in the United States. I think also that the Metropolitan Transportation Commission has a study going on to learn the effect of CMA on peach trees, in particular. I've suggested that they will find they have bigger, fatter, and better peaches using CMA because of the acetate content which will be highly nutritive. So in fact, instead of being sued for putting CMA on the peach trees, they may even be paid to do so. However, that remains to be seen.

Thirdly, research needs to be continued in the whole area of reduced salt dosage by various controlled policies. Reference was made to one policy in Metro Toronto which said that bad pavements at rush hours, instead of bad pavements, period, have a very serious impact on the amount of chemical being used. This is one of those unusual environmental situations where, by improving the environment, you also save money for the politician.

We have managed to educate our public to expect July roads in January. I suspect we could also do it the other way around with a certain amount of pain, but that would reduce the salt application. There are alternative road surface materials for which there is some hope. Most of the investigations are taking place in Europe. *Vagilmet*, for example, is a kind of road surface which leaches out calcium chloride, which prevents ice sticking to the pavement and, therefore, plowing is all that is necessary.

There is a considerable amount of research to be accomplished. I admire Environment Canada for inviting such a group as you together because it is absolutely true that the academics and professional research scientists have no idea how to run a snow plow and, therefore, they shouldn't be trying to tell people how to run snow plows and how to control snow during 3:00 a.m. storms.

QUESTIONS AND ANSWERS

Question: Mr. Raviolatti indicated that the first option is to leave snow by the side of the road. To me, the first thing you must do is to define what snow removal is; leaving snow in a berm on the side of the road, to my way of thinking, is not snow removal. Economics dictate that we will leave snow at the side of the road whenever we can. We are not deliberately going out trying to concentrate snow unless it is for a justifiable reason. Thus, the method is not really an option.

Response: Leaving snow by the side of the road is an option in a rural and semi-urban environment where the right-of-way width makes it possible to push snow to the side. In other urban areas where the shoulders permit, this is a method to be given preference. I know, for instance, that in the city where I live this is exactly what is done. Snow is pushed to the side of the road. We believe that this is perhaps the ideal method for causing the fewest problems because you are minimizing concentration. You are not concentrating contaminants in a specific place; you're dispersing them over the entire area. Of course, this is not applicable everywhere, only in certain places.

Question: Mr. Raviolatti indicated that the Government of Québec has commenced a study concerning the biological effects of sodium and chlorides and many heavy metals.

Response: Unfortunately, the Ministry of the Environment has not conducted many specific studies concerning contaminants. The Ministry of the Environment has confined itself for the time being to the review of studies conducted elsewhere. A bibliographic study has been done.

Comment: Both the Provinces of Québec and Ontario indicated that they have a preference for disposing of the urban snow on land. After the snow has melted the subject of cleaning up the site was mentioned. I would like the panel that is considering land disposal to look carefully at the final cleanup, the disposal of the soil from these land sites as well. The suggestion to register these sites so that people will know in the future what has been disposed of on those sites is a good suggestion. Representatives from both provinces have indicated that the soil will be disposed of properly. That is almost a throw-away line. We cannot assume that this will, in effect, be accomplished. I would like the land disposal panel to look at this as a very important issue, not just the snow disposal, but what happens after the snow has melted and contaminants remain.

Comment: I would like to comment that it is very interesting that, of all the panel members, only Dr. Jones mentioned briefly the need for education. I think that the greatest potential for improvement is to deal with the cause rather than the results. We have found in Calgary that education of our operators is very important. We help them to understand the calibration of the equipment and what it means when they are out there at 3:00 in the morning to want only a set amount of material to be distributed. We have looked at the results and we are very pleased. We have managed to reduce the amount of abrasives spread. Now our measurements are complicated by the fact that we have had two very pleasant winters. We can demonstrate, however, that we have made a very significant reduction in abrasive use. We increased somewhat the use of salt to compensate for the reduced amount of sand. We also have begun education programs for the public. There is a great potential for helping the public understand what our capabilities and objectives are.

Response: I agree that education is necessary. We are in a slightly different position. We use contractors almost exclusively and have taken the choice of application rate away from the driver. Controls normally are outside the cab and the rate is set by our supervisory personnel. Either the operator has to become an expert or you remove that operator.

Comment: In Minnesota a study was recently carried out with regard to the cost associated with using contractors. One of the things they did was to compare material use on two adjacent stretches of highway. They found that material use of both sand and salt increased significantly on the contractor's section, in the order of 30 to 40 percent, compared with the amount used by their own forces. Thus, the degree of control is a major consideration.

Question: I would like to know the proportions of snow which come from the public agency compared to that from private sources, such as parking lots and commercial places. In Sudbury, two-thirds comes off our streets.

Response: This is a problem that must be addressed. The problem we are experiencing is that more and more midnight haulers are dumping wherever they can. We supply enough security that they can't use our dumps. We recognize that it would be nice if we could let everyone use our dumps but we do not have the capacity.

Question: I would like to know if Professor Jones has any data concerning the microbiological characteristics of snowmelt water and additional information on the hydrocarbon content. The reason I ask this question is that in Edmonton, at least some of the runoff water has been tested using mass spectometer systems and 206 different types of organic compounds have been found in the runoff.

Response: There are a few pure microbiological studies available on the effects of sodium chloride and other salts, but particularly sodium chloride. When it comes to the organic contaminants there is one study that had to do with the control of taste and odour which resulted from hydrocarbons in the runoff water.

Question: I have seen in the documents that we were given at the beginning of this seminar that when the Province of Ontario voted to prepare its major guidelines relating to the disposal of waste snow they set up a working group with representatives from several municipalities, the Ministry of the Environment, and the Province of Ontario. I am also aware that the Ministry of the Environment of Québec has sent out a questionnaire to the municipalities of Québec that are concerned with the question of snow disposal. Does the Ministry of the Environment intend to set up a working group comprised of the representatives of the municipalities that use the snow dumping sites so as to develop major guidelines for the future?

Response: I was waiting for that one. Indeed, the Ministry of the Environment of Québec is proceeding somewhat differently than in Ontario. We have set up a working committee within the ministry which is composed of people who have direct or indirect knowledge of the removal of snow, disposal of road snow, contaminants, etc. That working committee has developed preliminary guidelines. We have already held consultations with some municipalities in Québec to develop these guidelines. As soon as the preliminary document is completed, we intend to do the following: we shall convey these guidelines to all concerned. Those most concerned are the municipalities. Once this has been done, we shall give them six months to send in their comments to us and as soon as we have received their comments, six months later presumably, we shall take these comments into account to finalize the guidelines. It goes without saying that if we receive vital comments from the municipalities, these being the primary bodies concerned, these specific points will be discussed in detail with the municipalities before we draft our final version of the guidelines.

UNDERSTANDING POLLUTION FROM SNOW MELT

Philip Niblett, Head, Environmental Group
Proctor and Redfern Limited, Don Mills, Ontario

I am going to bring a slightly different viewpoint to this meeting today. I am a biologist and I am going to bring that view. I am used to talking to environmental engineers, as Proctor and Redfern is comprised mainly of engineers. I'm also going to bring out a consultant's viewpoint which is a practical one which most of our clients tend to demand these days.

I want to talk about one concern I have, both as a biologist and as a consultant; that is the dollars we are going to be spending on environmental protection. Available funds must be spent wisely. To spend funds wisely we have to understand what we are doing, and as part of the process we have to ensure that the data collected is presented in a form that is understandable to the public. We have to get our message across as scientists and engineers. The concern for the environment is now more than a concern for the natural environment; it is one that includes social and economic factors. I would like to introduce the concept of an environmental profile. We have already had a review of many of the contaminants associated with urban snow. My premise is that disposal of snow is not a problem at all, indeed it is the pollutants that are contaminating the snow that should be our major concern. I hope this approach will aid the understanding of the consequences of what we do with the snow. I will use the Ottawa River as an example to explain this approach.

As noted by other speakers today, each site is different and therefore each solution will be slightly different. Ottawa has certain constraints and certain opportunities that were utilized in designing the disposal option for that city. Ottawa has had problems similar to those of many other cities that have been described earlier, such as the spread of housing into areas formerly used for snow disposal and opposition to the noise. This has resulted in the restriction of the hours for which certain sites could be used, restricting the total capacity, or the banning of certain sites altogether. Due to a growth in public concern, Ottawa-Carleton Council hired consultants, both engineering and environmntal, to look at this problem. The terms of reference given to me were quite general. I was asked to investigate the option of direct disposal into the river, to review alternatives to direct disposal, and to determine the acceptability of a particular site as a direct disposal site. Now conditions in Ottawa were more favorable than perhaps in many other areas in that direct disposal appeared to be a viable alternative. We had an average winter flow past the site of approximately 1 000 cubic metres per second. The river has a velocity of about 2 metres per second which results in a very high turbulence and a great capacity for mixing and dilution. The site to be studied was located in an industrial area.

The ratepayer groups that had been a factor in the consideration of other sites were not a prime concern at this site. Implied in our contract was the public participation aspect. That is why I selected the environmental profile approach. It is simply a formal way of expressing what may have been done before. It is nothing new, but the method is an organized approach we used to present our analysis to the public. It was designed to promote more intelligent decisions to be made based on a comprehensible information base.

As we have already heard, there is a need for additional data. The first process we went through was a description of the problem, the snow contaminants, and the direct disposal characteristics of the site. The second process was to project future concentrations and the impact with or without the project on all environments: natural, social and economic.

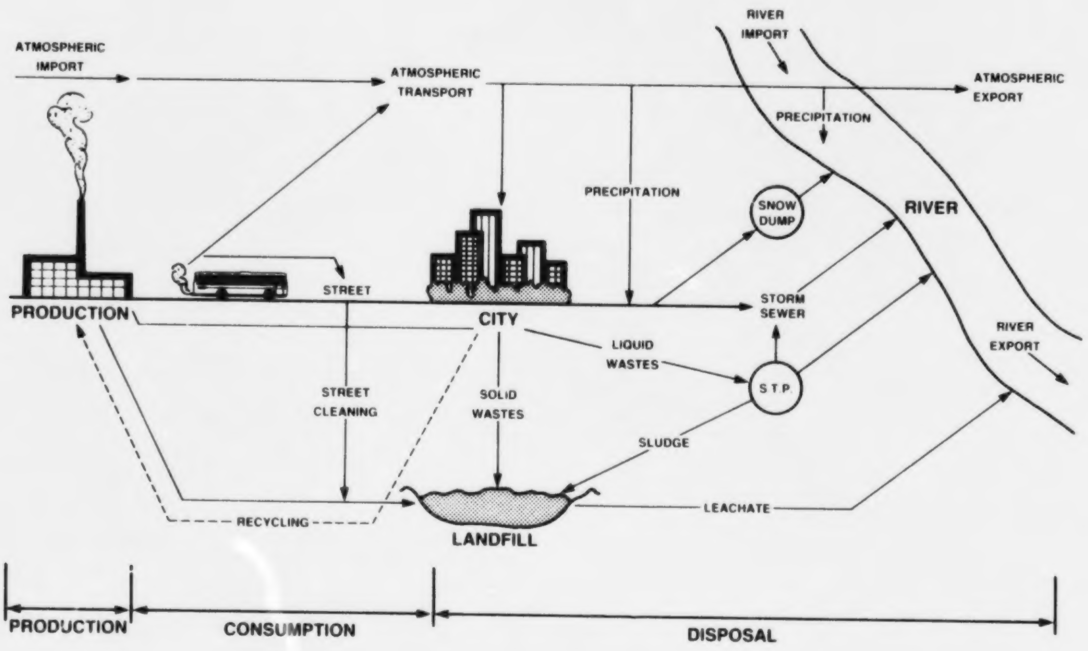
To accomplish this, we set out to profile all sources, transport mechanisms, and present and future concentrations of contaminants associated with snow. This resulted in, first of all, a qualitative view of pollution movement associated with snow. Then we tried a more difficult task of quantifying those qualitative impacts. We compared predictions against existing objectives, criteria, or guidelines for the absolute impact. Were we meeting criteria? We then compared the option against not taking the action. Is the impact of the go, no-go option significant? What is the impact in absolute terms if we do meet objectives? Are we changing the status quo? The significance of the proposed action was identified and, even more important, the effective point of intervention was identified. Even if from a biological basis there is not reason for concern, whether you dump snow directly into the river or in a quarry or on a river bank, the intervention points need to be known. For example, if it was decided by Environment Canada, or the Ontario Ministry of the Environment, that removal of lead was a priority, by profiling the dynamics of this pollutant in the environment, it became very obvious that there were specific points at which control would be more effective than at others. Thus, we could enhance the dollars spent on control and be more effective. With the profile we could not only identify the cost, but also from a social and natural environmental view point, the optimum solution could be identified.

The first step of our study was to identify the pollutants. We characterized them into major and minor. Based somewhat on available information, but also based on potential hazard, the toxicity associated with particular compounds was determined. We described the major pollutants as lead, chloride, biochemical oxygen demand (or oxygen demanding substances), suspended solids, sodium, and calcium. Our minor pollutants were oil and grease, cyanide, chromium, phosphate, sulphates, iron, Kjeldahl nitrogen, ammonia nitrogen, phenol, coliform bacteria, volatile solids, and zinc. This list was based primarily on our literature review.

During our very early contact with the public, it became apparent that there were two additional concerns that should be considered. One was garbage. Also sodium became much more important later on in the public consultation process. The two prime concerns, however, which came up at every meeting were lead and chloride. Those are the two environmental contaminants that everyone seemed to be focusing in on. We concentrated our effort on those particular two. Rather than go through a complete profile for everything, I have selected lead as an example of the profiling approach we took to illustrate my talk today.

Lead, I think, was the most significant contaminant if we can use public and elected official response to the list of contaminants. It certainly came up time and time again as our most important contaminant. We looked at the sources of lead as we tried to understand its dynamics. I have divided lead into two sources, natural and manmade. The natural sources we defined as geological weathering, forest fires, and volcanoes. There is little to no control over such sources. Manmade sources included production, such as mining and activities associated with production of lead including manufacturing after the lead has been incorporated into various products. Consumption is also a very large category which includes many things, the most important being leaded gasoline. Disposal is another source that is not only associated with the production process but is also associated with use. For example, water going through the system in leaded pipes is taken to the sewage treatment plant and these plants become another source of lead to rivers. Oiling roads, incineration and all activities where lead is used by the public and eventually disposed of are other sources. And then, there are inadvertent manmade sources. By doing some type of activity not concerned with production or consumption, entry of lead into the environment is allowed. Examples include incineration of fossil fuels, production of cement, and various similar activities. Figure 1 traces the use and fate of lead in urban areas.

The data on lead were excellent and that was certainly a factor in its favour in terms of defining where it was coming from and where it was going, as shown in Figure 2.


ATMOSPHERIC IMPORT
ATMOSPHERIC TRANSPORT
RIVER IMPORT
ATMOSPHERIC EXPORT
PRECIPITATION
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SNOW DUMP
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STREET
PRODUCTION
CITY
STORM SEWER
RIVER EXPORT
LIQUID WASTES
S.T.P.
STREET CLEANING
SOLID WASTES
SLUDGE
RECYCLING
LANDFILL
LEACHATE
PRODUCTION
CONSUMPTION
DISPOSAL

FIGURE 1 DYNAMICS OF LEAD IN THE URBAN ENVIRONMENT

In 1972, there were approximately 17 000 tonnes of lead emitted to the atmosphere in Canada. Of that, 12 000 tonnes or 71 percent came from automobile emissions. This is by far the largest single source of this element. As we were trying to project changes with or without the project we also looked at trends in lead consumption. Between 1971 and 1982, according to data from the Ministry of the Environment for Ontario, the consumption has decreased gradually.

However, it has been suggested that there is now a trend back to leaded gasoline because of the price differential. Unleaded gasoline is much more expensive. As a result, the former Minister of the Environment, on March 9, 1983, called for a reduction in the concentration of lead in leaded gasoline. I predict that future lead use will continue to decline. From such information we produced a conceptual model of the dynamics of lead in an urban setting. It was at this stage that the reliability of the data decreased. There are many pathways of lead into the Ottawa River, as shown by Figure 3. The proposed snow dump is only one pathway and one pathway that is only operational at specific times during the winter. There are many other sources, some of which we could quantify and some of which we could not. This again points out a need for research. We

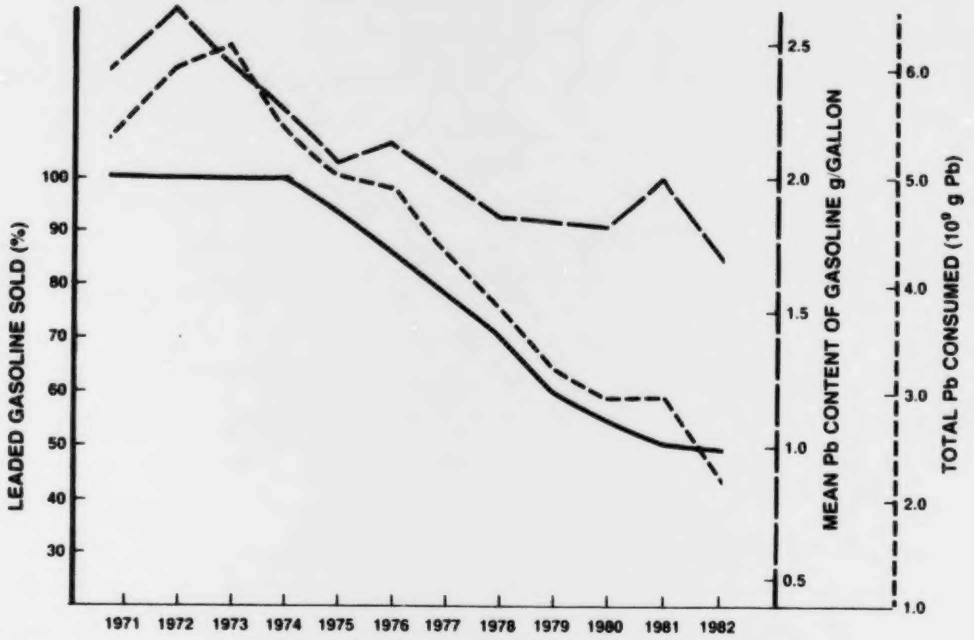

FIGURE 2 LEAD CONSUMPTION IN GASOLINE, CANADA, 1970-82

looked at the total lead flux into the Ottawa River. We did not find any information on Québec or Ontario industries so those particular additions to the river were left out of our calculations. We did this to try to be conservative and develop a worst-case scenario. Now even without industrial emissions, the total lead from the snow dump itself is quite small in comparison to all other sources entering the Ottawa River above Ottawa. In fact, lead from snow represents about 0.03 percent of the total lead going into the river. However, total lead, as I already mentioned, is perhaps not as relevant because the toxic forms of lead are soluble ones.

Lead from automobile exhausts is very insoluble. Lead by itself is inherently insoluble because of its chemical properties. But somehow the material that comes out of automobile exhausts is even more insoluble. Consequently, the loading from the snow dump represents only 0.02 percent of the total soluble loading to the Ottawa River snow dumps which indicated that the lead was irreversibly bound to particulates. The second study I did myself on the Humber River in Toronto. In Toronto we have not taken care of our rivers as well as we should have. Some are little more than sluiceways. In one section of such a stream, I sampled a small pocket of accumulated sediment. This location

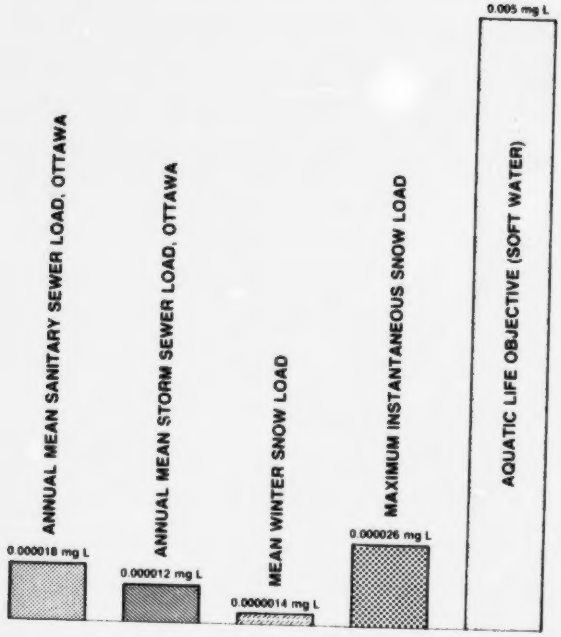

FIGURE 3 ESTIMATED SOLUBLE LEAD LOADINGS TO THE OTTAWA RIVER

received direct runoff from Highways 400 and 401 so the high lead content could be equated to automobile emissions. The sediment was a strange material. My first reaction when I saw the analytical results from our laboratory was that perhaps they had not been as accurate as possible since the value was higher than the lead I found associated with smelting operation sediments. I went down to the lab and examined the residue. The lead could be removed from the dried sample of sediment with a magnet. Lead is not magnetic, so obviously there is something else associated with it. This is a fertile area for research as to what lead is bound up with and what form it is in. Back to the Ottawa River, however, we next estimated the soluble lead loading to the river and compared it with existing published criteria to see where we stood, using a worst-case scenario. The maximum instantaneous load produced from the snow dump was approximately one-half of one percent of the published criteria or objectives.

Public concern tends to focus on human health, and there are concerns about lead. I reviewed the literature on where lead taken into the human body originates. Here we were concerned about drinking water. I found out that of the daily intake of approximately 180 micrograms of lead per person per day, 140 micrograms comes from food, 20 from water, and 20 from air. Again, the intake is perhaps not the most critical factor in that we want to know how much is absorbed. From food it worked out to be 14 micrograms, from water 2, and from air 8. So it seems that if we are concerned with lead burden in the human body, we should direct our efforts to food, air and water, in that order. We should concentrate on the major sources before we start concentrating on minor ones.

There has been some recent work done on acid precipitation and its effect on drinking water systems which may change the numbers that I have used, but they are not related to snow disposal.

Having completed the profile of lead in the Ottawa River, we went one step further, and that was to project loads. The questions we were trying to answer were: How do the alternatives we have available for disposal alter the present status quo? What's happening today? How is what we are planning to do going to affect the government? (Figure 4).

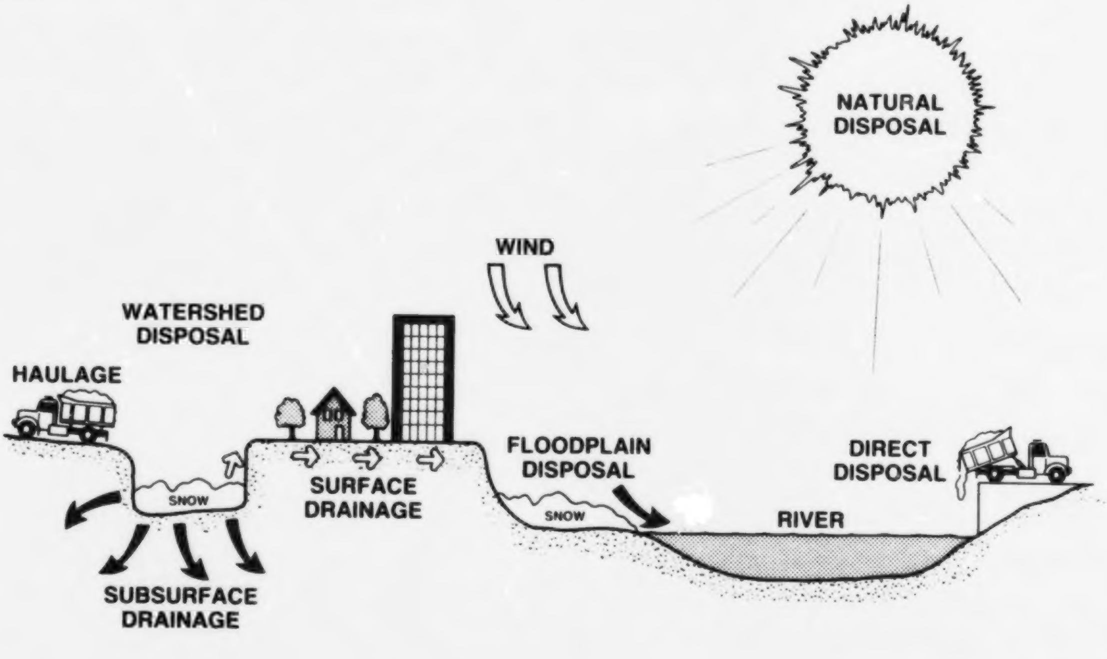
NATURAL
DISPOSAL
WIND
WATERSHED
DISPOSAL
HAULAGE
SNOW
SURFACE
DRAINAGE
SUBSURFACE
DRAINAGE
FLOODPLAIN
DISPOSAL
SNOW
RIVER
DIRECT
DISPOSAL

FIGURE 4 SNOW DISPOSAL OPTIONS

Presently, as we have heard, vacant land is a good place to put snow, but vacant land is being built on and becoming very scarce. That tends to leave floodplain areas or quarries. As I've already indicated, lead is very insoluble; therefore, if the area is not cleaned up, and I don't mean just the loose debris but rather the lead particulates, we may have major problems. Lead particulates are susceptible to wind erosion since they do not percolate down into the soil profile, and they also may be transported by sheet erosion. Therefore, following the model we have constructed, the impact of what we are proposing to do, which is direct disposal into the river, was to change the time it takes the lead to reach the river. It's the only change. We are not creating any more lead, we are only relocating it.

I reached the conclusion that the impact of snow disposal was negligible. I even went so far as to say that it was immeasurable. On my last presentation before the Council, there was a group from Carleton University present. Unknown to me they had done a class project on this particular study, looking at all the contaminants, not just lead, and they used a hazard evaluation approach which I thought was very effective. They looked at the potential harm of the substance, or toxicity, the way it affects human beings, and the potential for exposure to that pollutant. It was a combination of these two factors that led to their conclusion that river disposal is preferable to land disposal, mainly because the exposure potential for human beings is less. Thus, disposal in the river is the best disposal option currently available.

The only caution I would have is that if we are wrong, the cleanup is immeasurably more difficult if lead is dispersed into a river environment than if it is dispersed on a land site.

We went through the same environmental profile projections for other contaminants associated with snow, and we reached essentially the same conclusions. We are not affecting the status quo. Chloride is another example which behaves entirely differently from lead. It is very soluble. But again, putting it into the river or putting it beside the river really did not seem to have great biological consequences in the system. It did not affect the status quo. We say nothing about the status quo, whether it is good or bad. Such a judgement was beyond our terms of reference, but we did look at it briefly. We concluded that from the values we were talking about, based against established, published criteria by the Ontario Ministry of the Environment and Environment Canada, we are still well below the criteria due to the huge dilution capacity available in the Ottawa River.

Such evaluations perhaps leave the scientific and enter into the public or political realm. There is some concern about any concentration of lead, and I think I would share that concern. We just have too much lead in the environment to begin with. We're not changing it with this particular proposal; there is too much now. That led to a need to identify the area of the most effective dollars to remove lead, then I don't think we need to talk about how we are going to dispose of snow. We need to talk about how we are going to reduce or eliminate lead from the primary source, which is gasoline. Likewise, we do not need to talk about where we are going to put the snow because of the chloride content. Chloride is so soluble that it is going to get into the river. We may slightly change the rate that it is going to get into the river. We may slightly change the rate that it is going to get there, but it has a miniscule effect in the Ottawa River. Another concern, garbage, was a particular concern in the Ottawa area. There are management options, e.g., do not collect snow on those streets where garbage collection is scheduled and when there is a snow storm. Once the pollutant, whether it be lead, chloride, or garbage, is mixed with snow, it is an academic exercise as to whether to place it beside the river or directly into the river, whether it is slowed down a little bit, or percolated into the groundwater.

The issue of the location of the dump should be decided on an economic or social basis. The biological consequences were not sufficient for selecting one site over another. Now what I have said relates strictly to the Ottawa River, which has a large capacity for dilution. Other locations will be different and will require their own assessment.

One of our conditions of approval was to monitor. We have just completed our baseline study on the Ottawa River and I found out an engineering fact of life, something called frazil ice. There's a lot of it. The various characteristics that we found desirable for dilution were very conductive to promoting frazil ice formation. What happens is that when we have very fast moving water it doesn't freeze. The water still becomes cold; in fact it becomes supercold. And this supercold water forms little ice pellets underneath the surface ice. When the velocity slows enough the ice pellets float up and a dam is produced. It's called a hanging dam and it fluctuates daily, perhaps even hourly. On the Ottawa River it forms a very large dam. At some of our sites we had 20 metres of this stuff to sample through, which produced some problems. That, plus a wind chill factor which seemed to always be minus 40 degrees, became very obvious to me when sampling over a 24-hour period. I could feel the frazil ice moving. Everytime I went to a station, the location stayed the same, but the frazil ice moved. This led to a large sampling error.

If you keep your station location the same, but your river hydraulics are changing continuously, the variation you are going to get in your sample has nothing to do with any loading that you are receiving from upstream at all. My initial reaction was that I was looking for a needle in a haystack out there to begin with, and that background variations would be high. We expect to have much of the pollutants in the nearshore and less out in the mainstream current. Well, after experiencing this problem with frazil ice, I am now less optimistic that we are going to obtain accurate measurements. We tried a dispersion study, to detect exactly where the currents were going. We couldn't find the dye. So many things are happening out there that monitoring snow dump impacts will be very difficult indeed.

I have come to the conclusion that the most effective point of monitoring is where we can actually detect the presence of some contaminants. This is not in the river, as most of my samples indicate less than one part per billion for lead. We know what the sources are. In order to determine the impact from the single source, the snow disposal site, we should monitor the trucks as they arrive at the site or the snow on the roads. We will still have to use a dispersion model to predict the impacts, but at least we are refining the numbers that we have available to make those impact predictions. This approach will lead to more intelligent decisions on what we should do with snow.

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QUESTIONS AND ANSWERS

Question: Seventy-one percent of the lead in the environment comes from automobile exhausts, as shown by the model. We have tried in the Municipality of Ottawa-Carleton for two years to get the federal government to change the price of lead and nonleaded gasolines. I am under the impression that there is a difference of less than two cents per litre in production costs. If we could vary the cost of nonleaded gasoline, making it not a specialty item but a run-of-the-mill item we could reduce lead consumption by a major amount, yet we have obtained no response from the federal government at all. The second point I want to make is to expand on your statements concerning the effect of insoluble leads that have gone through an internal combustion engine. I wonder if you would expand on what they appeared like under a microscope. I believe that the results found were a thousand times the chemical concentration found in nature.

Response: Again, the data is less than a scientist would really like to look at. The particular sample I had referred to was from the Humber River. When you looked at it under a microscope it appeared to be tiny cinders. It was like a very tiny coal ash, a very solid particulate matter. In other studies a leaching effort subjected the lead to a very high pH. This study provided some of the rationale for the study by the Carleton students. The particulate material is disposed of upon a land site. It is exposed to the elements and the rain isn't pH 7 in Ottawa. The pH is closer to 4 although I don't have firm figures on that. When you start getting the pH down you are increasing the susceptibility to leaching and their analogy was that the Ottawa River will not get down to a pH of 4 and, therefore, the pH buffer of the Ottawa River will reduce the potential of lead solubilization, and hence its biological availability.

Comment: The question of solubility of lead worries me because I think it has been pretty well demonstrated that lead can be methylated the same way that mercury can be methylated. Any short-term tests are unlikely to produce any meaningful solubility data. If all of the lead reaches the river, all ends up in the sediments, and goes through this methylation process, all the lead is ultimately going to become soluble. So I cannot really see short-term leachate tests, particularly in high pH, giving you any sensible prediction as to what is going to happen to the lead.

Response: May I suggest that that is all the more reason why we should control the source by simply changing the price, by a few pennies, between lead and unleaded gasolines.

Comment: I would like to point out that there are a lot of differences in lead and mercury. They behave quite differently especially in methylation. There have been recent studies that indicate that lead does methylate. It methylates and gets into biological organisms, it bioaccumulates. There is evidence that lead accumulates up the food chain. The studies done by the Ministry of the Environment on the Toronto Harbor, on Hamilton Harbor, and various areas like that do not find this food chain effect; where as you go up the food chain you have an increase in the lead burden. The only analogy made is that the absolute concentration of lead in the sediments seems to be related to the body burden of fish, in particular, benthic feeding fish such as suckers and catfish. There is a correlation there, but unless you are aware of any evidence that indicates it has methylated like mercury and goes up a chain, I would suggest that perhaps it does not happen; at least, it hasn't been detected.

Response: To speak to the point, there are a couple of studies that do talk about organic leads in either aquatic birds or fresh water and marine fish. Much of the data, however, are preliminary. Wong at the Canada Centre for Inland Waters in Burlingon has been looking at some freshwater fish. Yes, there are low levels of detectable levels of organic lead in the fish. The question we have to interpret is that in terms of the toxicity of the substances and with respect to the organic leads, we have very little information on the toxicology of those compared to inorganic lead. It does exist. Whether it's because of methylation or organic lead species that get out either by evaporation or spills, etc., we are not absolutely certain, but there is evidence to indicate that lead is there and is being taken up by the aquatic biota.

In considering lead from automobile exhausts, according to the information sources I have reviewed, one-third of the lead that is deposited is very close to the highway. It doesn't go far. The other two-thirds seems to travel great distances and can be detected in the ice-caps in Iceland and Greenland. The correlation there is quite dramatic; you can see the introduction of leaded gasoline into the world economy and the increases. It has obviously been transported long distances. Is two-thirds of the lead emitted a different form of lead? I think we are just showing our ignorance as scientists - we really don't have that information on hand right now. We must deal with this problem without having all the facts.

Question: The problem of sampling, particularly in storm water, snow dumping, and such, is extremely difficult. We found this to be very true for storm water. You mentioned your concept of sampling the material as it arrives at the disposal site. I was wondering if you have developed any procedures for such sampling or done any type of analysis as to the number of samples that are required to get something that is valid. Obviously, you have got a nonhomogeneous mix and it concerns me as to how you sample or how often or how many samples are going to have to be taken to come up with a mix that is appropriate.

Response: Up to now we have not looked at the sampling procedure because our directives from the Ministry of the Environment, which is responsible for giving us permission to build this particular facility for direct disposal, were pretty explicit. They wanted samples from the river. It is an expensive proposition as well as difficult to obtain representative samples. We do not have a program established for sampling the trucks as they arrive at the site. We have discussed this informally but we have not really put a lot of thought into it.

Question: If all the cities of the region were to unload into the Ottawa River, would your conclusion still be the same?

Response: I don't know all the municipalities in the Ottawa Valley; however, I would suspect that the lead is already going into the various tributaries. I do not know how long it will take to reach a state of equilibrium. The lead will be transported downstream according to my model and according to the evidence that I have. What we are concerned about is the rate. So all the lead, unless it is removed from the system, is going to end up in the Ottawa river anyhow, if it is produced in the Ottawa River basin. On a geological time scale it doesn't make any difference. There may be site-specific areas that already have high loading sources where you could have localized problems; I really don't know.

Comment: A point regarding the request to the Department of the Environment to change the price of leaded gasoline; it isn't that they have not replied, the Department has indicated that they are taking another course to reduce the total lead. However, we find it very difficult to find out why such a simple move which perhaps could be carried out by requesting the major oil companies to change their pricing on behalf of the environment and institute an overnight change is not being considered. The Department has replied courteously that their efforts will be to reduce the amount of lead permitted in gasoline.

Comment: The City of Chicago has eliminated the use of leaded gasolines for its own fleet and have an ordinance prepared to ban the sale of leaded gasoline. The concern in Chicago is for the lead in the environment and its effect on children. As far as I know, it is the first major effort in the United States to attack the problem of leaded gas. Whether or not the oil companies are going to be able to sidetrack the legislation remains to be seen, but at least it did get through all the council committees.

Comment: I think that it is impractical to ban leaded gasoline. There are too many vehicles on the road that require leaded gas. I think that if they change the price of gasoline people will quickly make the choice and this is the best way, if you can.

SNOW DISPOSAL IN MONTRÉAL

Richard Vanier
Director, Service des travaux publics
Ville de Montréal

Introduction

Our participation at this conference reflects the keen interest our municipal government has always had in protecting the environment and safeguarding the quality of life of its citizens. This is indeed an exciting opportunity for us to exchange expertise and knowledge with representatives of other cities and organizations who are here today, and we are confident that the next two days will be valuable ones for all concerned.

The City of Montréal and its public works department have, of course, wide-ranging experience in the removal, loading, hauling, and disposal of snow. For decades now, we have done what is necessary to provide Montrealers with fast and effective snow disposal services and a wholesome urban environment in which to live. As part of this effort, the Service des travaux publics (STP) has, over the years, developed snow disposal methods adapted to Montréal's particular needs and compatible with environmental concerns. One such method involves sewer chutes and the full use of the city's sewer network. It has also developed the innovative technique of using a quarry as a huge receptacle for snow disposal.

To better explain why Montréal has opted for certain of these methods, we shall begin with a geographic, social, and climatic profile of our city, to be followed by a brief description of these various techniques. A second section will focus on the environmental considerations that must be addressed and those methods that we recommend. And a final section will deal with what the future holds in store, an aspect no less important since Montréal does and will continue to explore new approaches to snow disposal.

Although the winters in Montréal are consistently harsh, the city's urban character is an everchanging one. We therefore owe it to ourselves to adapt to the social, economic, and environmental demands it makes upon us.

1. Montréal - A Profile

A brief description of Montréal's geographic, social and climatic characteristics, to begin with, will help to better understand the city administration's policies and actions regarding snow removal and disposal.

1.1 **Physical Description.** Montréal is an island surrounded by one of the world's most beautiful rivers; located in the centre is Mount Royal overlooking the downtown area. Greater Montréal, known as the Montréal Urban Community, is the seventh largest metropolitan area in this hemisphere.

The City of Montréal proper has a total area of 175 km^2, or one-third of Montréal Island, extending 25 km along the St. Lawrence River and meeting the mouth of the Des Prairies River 15 km to the north. The city's road and pedestrian network consists of 1850 km of roads and streets, and 3365 km of sidewalks.

1.2 **Population.** The City of Montréal has a population of 1 018 000, or 16 percent of the provincial population. The city's population density is 5834 per km^2. A city-commissioned survey found that 63 percent of Montréalers who travel about other than by walking prefer taking their car over public transit. During certain months of the year, as many as 796 000 vehicles from Montréal and the outlying suburban areas use the city's streets and roads daily.

Montréal is a dynamic city, with a bustling and everchanging social, economic, and cultural life.

1.3 **Climate.** Montréal has a wide-ranging climate with hot, sunny summers with an average temperature of 21°C.

Indicative of North America's unpredictable climate, however, the winters in Montréal are long and harsh, lasting as long as five or six months; from November until April just about anything can happen. In fact, the major feature of our winters is precisely their capricious nature. Sudden changes in temperature, unexpected storms, violent winds and bitter cold temperatures down to -30°C are just some of the things Montréalers have come to expect.

An average winter may include up to 40 or more snowfalls, about 10 of which will dump 15 cm or more. According to an Environment Canada survey of snowfalls in major Canadian cities between 1951 and 1980, Québec City ranked first with an annual snowfall of 343 cm; Montréal was second with 235 cm, followed by Calgary, Toronto and Regina, with 152, 131, and 115 cm, respectively. The heaviest single snowfall in Montréal occurred in 1970, dumping a total of 75 cm.

These figures show how important it is for Montréal to do all that it can if it is to provide its citizens with a safe and efficient road network at all times. This has meant ensuring snow removal operations that are properly organized and well coordinated.

A Montréal street after a winter storm.

2. Montréal's Snow Removal Operations

The City of Montréal has entrusted to its public works department the responsibility for snow removal and disposal as well as all general maintenance of the city's street and road network. To carry out its mandate, the department has a work force of nearly 2000, and some 1600 pieces of equipment, and relies on the services of private contractors when cost-benefit factors allow.

To ensure fast and efficient operation, the department has divided the city into 89 zones (each containing about 20 km of roadway) which have to be cleared simultaneously. The department is currently responsible for snow removal in 44 of these zones; the remaining 45 are cleared by private firms under municipal supervision.

There are three stages to Montréal's snow removal operations:

- the spreading of salt and abrasives
- the clearing of sidewalks and roadways
- the loading and hauling of snow to disposal sites

2.1 **Salt and Abrasives.** The City of Montreal has 93 mechanical spreaders, each equipped with an automatic release control calibrated to ensure minimum use of deicing substances. Once a snowstorm begins and until 8 cm have accumulated, the department will make use of these spreaders, first on hills and major arteries, then on secondary roads and residential intersections.

Each year, the department uses approximately 100 000 tonnes of salt, 25 000 tonnes of crushed stone (5 to 6 mm in diameter) and 17 000 tonnes of sand.

2.2 **Sidewalk and Roadway Clearing.** When snow accumulation reaches 2.5 cm and the snowfall continues, spreading operations are gradually halted and clearing equipment begin their work across the city until the snowfall has ended. On the average, these clearing operations can last anywhere from 12 to 24 hours.

2.3 **Snow Collection.** Snow collecting and hauling begin as soon as snowfall ceases. The snow is first plowed into swaths or windrows which are then picked up by a blower and transferred into dump trucks. The city has worked out a precise schedule for snow collection so that roads can be cleared for vehicle traffic as soon as possible:

- 72 hours for an accumulation of less than 20 cm.
- 84 hours for an accumulation of 20 to 25 cm.
- 96 hours for an accumulation of more than 25 cm (may be extended if need be).

3. Snow Disposal

The City of Montréal disposes of some nine million cubic metres of snow each year. It has had to exercise a great deal of care in selecting appropriate methods to handle this vast quantity of snow. Specifically, the department of public works has had to look closely at the operating costs for each method and carefully study relevant government recommendations.

On December 21, 1983, Québec Environment Minister Adrien Ouellet made public specific methods his department recommended for snow disposal in the province. These methods, which were based on various environmental criteria, were in order of preference:

- piling along roadways
- land dumping
- use of melters
- sewer dumping

A Montréal street after a winter storm.

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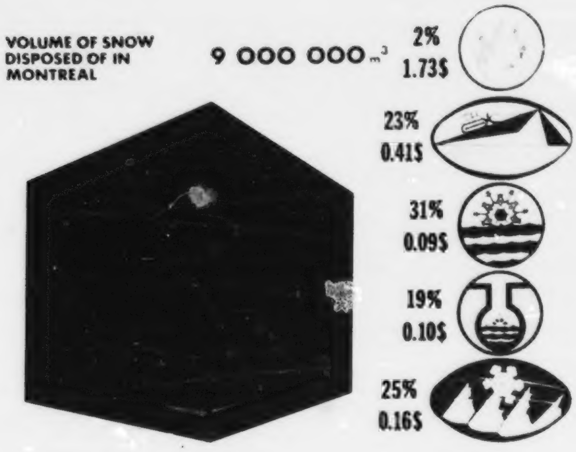


The department said that it would allow disposal in watercourses in special cases but only after careful study had shown such recourse to be justified and environmentally safe.

That same month, the Québec Ministry of the Environment (MENVIQ) released a report entitled *Lignes directrices pour l'élimination des neiges usées* (Snow Disposal Guidelines) which listed the major sources of environmental contamination and the problems associated with poor disposal site location, operation and management.

MENVIQ singled out a number of contaminants that could affect soil, surface and underground water, and all living organisms, including humans:

- deicing chemicals such as sodium and calcium chloride
- lead particulates from leaded gasoline
- abrasives such as sand and fine gravel
- iron and zinc particulates from metal corrosion
- phosphorus (anticorrosive agent associated with salt)
- oil and grease from motor vehicles

The department also points out some of the more significant problems associated with the different methods and sites used.

3.1 Piling Snow Along Roadways

- possible blockage of sunlight during part of winter, for homes and other buildings situated near snow piles
- possible adverse effect on trees and lawns, causing delayed growth in springtime

3.2 Land Disposal

- ugly and unhealthy appearance: blackish crust and land strewn with refuse and other debris after thaw
- possible flooding of adjacent land due to poor drainage during thaw

- possible disagreeable odours in springtime
- risk of creating microclimate (local fog) in spring

3.3 Disposal in Sewers or Use of Melter

- possible blockage or breakage of sewer system
- large volumes of excess water introduced into system (sanitary sewer or mixing conduit)
- pollution of watercourse if no intermediary treatment system in place

3.4 River or Lake Dumping

- risk of flooding or creating obstructions such as ice jams
- possible erosion of bank at dumping site
- possible encroachment of watercourse jurisdiction in certain cases
- pollution of watercourse, including bed and banks, and resulting in cleanup problems

MENVIQ is also quick to point out some of the problems common to all of the methods used:

- noise from heavy vehicles during operations
- the possible depreciation of adjoining residential property

The city also uses a method which, to our knowledge, is unique to North America, and that is snow disposal in quarries. Before adopting this original technique, the public works department identified a number of definite advantages:

- site located in an industrial area
- opportunity for sedimentation of solid waste
- meltwater could be pumped into sewer system
- large disposal capacity
- low operating cost

Some of the problems to be worked out, however, were:

- vehicle movement in and around site
- site security (lighting, fences, signs, and control huts)

4. Current Snow Disposal Methods

On the basis of relatively low operating costs and, above all, its commitment to prevent or minimize the human and environmental problems caused by snow disposal, the City of Montréal uses five disposal methods:

- land disposal
- mechanical melters
- sewer chutes
- river dumping
- quarry dumping

These methods, incidentally, are all consistent with the government recommendations cited earlier.

The department of public works based the operating costs for these various methods primarily on manpower, equipment, nondurable goods, miscellaneous services, site rental costs, and the amount of snow hauled. (Data compiled over the last five years indicate the winter of 1981-82 as best representing the average winter season. We have therefore included, as an appendix, a document entitled "Operating Costs of Snow Disposal Sites, Winter 1981-82" which gives a cost breakdown according to either site or disposal method.)

4.1 **Land Disposal.** The department currently operates a total of 13 land disposal sites, either rented or owned by the city; these sites account for 23 percent of all snow disposed of in Montreal.

4.1.1 **Treatment.** Land disposal involves simply piling snow on a large land site; the truck dumping the snow uses a raised access ramp for this operation. When the pile reaches the height of the ramp, the snow is packed down in such a way as to extend the ramp, allowing further piling and better cost-effectiveness.

4.1.2 **Environmental considerations.** The department carefully studied each proposed dumping site before deciding to use it and, in each case, considered many factors to ensure effective site management. It selected sites located in commercial or industrial areas only, so that the fewest possible residents were affected by the noise and inconvenience cause by heavy vehicles.

Furthermore, only sites with excellent drainage were chosen, ensuring that, come spring, the water from the melting snow could make its way into the municipal sewer system and eventually to the sewage treatment plant. As a final consideration, the sites had to offer adequate access for heavy vehicles and be large enough for disposal operations.

In accordance with government recommendations, the city makes every effort to ensure that disposal sites do not harm the environment and are safely operated. As an example, the city placed a tree belt on each of the sites it owns to act as a protective barrier against noise and to improve overall site appearance. In fact, these same sites are used for recreational purposes in the summertime. For security, the city provided each site with proper lighting and fences, as well as huts for controlling traffic in and out of the site area. Similar facilities are installed on sites rented by the city, but these are usually only temporary.

Despite its many advantages, this method will be used less and less. Part of the reason is the population shift back to urban areas which has taken place over the last few years. Montréal has responded to this trend with a large-scale housing program called *Opération 20 000 Logements*. In addition, the city administration has made quality of life a top priority and is now emphasizing its green space development policy.

As a result, the city will have to shut down some of its dump sites and find alternative solutions as vacant land within the city becomes increasingly scarce and legislation prevents the use of industrial land for other purposes (Québec Industrial Funds Act).

4.1.3 **Operating costs.** The department determined that the cost of operating land disposal sites in the winter of 1982-83 was $\$0.41/m^3$, broken down as follows:

- equipment (68%)
- manpower (29%)
- miscellaneous services (3%)

4.2 **Snow Melters.** The City of Montréal has four Trecan and Geyser snow melters, only one of which is currently being used, accounting for two percent of total snow disposed of. All four melters are located on land belonging to the city, three in the west and one in the east.

4.2.1 **Treatment.** The disposal process for melters is simple: oil burners are used to heatwater in large melter basins. The snow hauled by truck is dumped into the basins and the resulting snow and water mixture passes directly into the municipal sewer system and eventually to the sewage treatment plant.

4.2.2 **Environmental considerations.** The department considered many factors before deciding where to install its melters. First of all, they have to be linked up to the municipal sewer system. The city then decided to install their melters in areas of low population density, namely commercial or industrial areas.

The city pays much attention to aesthetics and security at the melter site as well. As with its land dump sites, the city built a barrier to reduce noise and improve appearance. The same security facilities have also been installed, including a light system, fences, and control huts.

4.2.3 **Operating costs.** Last winter, the cost of operating the city's snow melter came to \$2 per cubic metre. Much of this amount was due to the cost of oil; a melter can consume to 850 000 litres of oil a year.

In 13 years, the operating costs for a snow melter have increased from a mere \$0.39 per cubic metre to \$2 per cubic metre. Because of this tremendous cost increase, the city prefers to use melters only in an auxiliary capacity or to offset large hauling distances.

4.3 **Sewer Chutes.** The city decided to use its sewer network for direct snow disposal after careful evaluation of its potential. Montréal's municipal network contains15 large collectors with a flow rate sufficient to carry 20% of the city's waste snow to its sewage treatment plant.

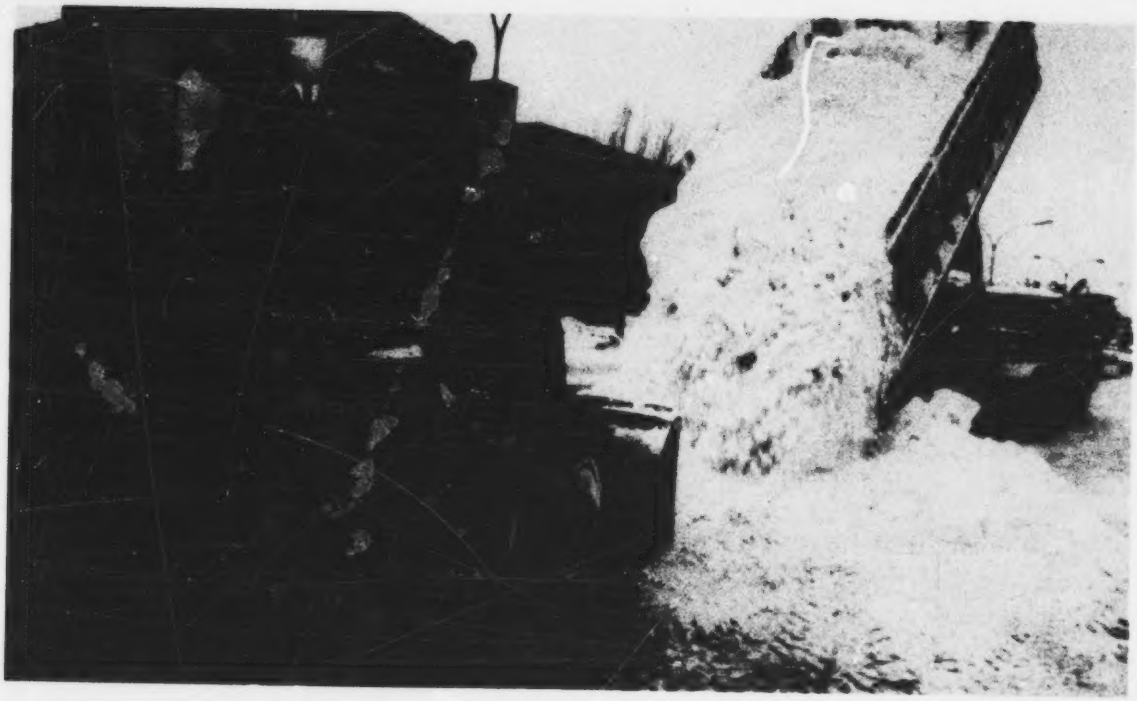
4.3.1 **Treatment.** The process begins with trucks dumping their loads near the sewer chutes. The snow is taken by a front-end loader and dumped directly into a collector, passing through the system and eventually reaching the treatment plant at Rivière-des-Prairies.

4.3.2 **Environmental considerations.** As in the case of melters, sewer chute sites are chosen on the basis of collector capacity and the ability to accept large quantities of snow without blockage or pipe breakage. The collectors must have a minimum diameter of two metres and a flow rate of at least 2 m^3/s. In this case, water from the snow is also sent to the treatment plant.

Construction of the north interceptor is now completed and, beginning this winter, will be able to send all the snow collected in the sector to the treatment plant. Completion of the south interceptor is not expected until 1990.

The city selected sewer dump sites in commercial and industrial areas, again to minimize the environmental impact of heavy-vehicle traffic (15 trucks an hour per contract). Similarly, a protective barrier, fences, control huts, etc., have been installed to reduce noise, improve site appearance and ensure site security.

In keeping with its green space development policy, the city uses most of these sites as recreational parkland in the summer.



Sewer dumping: the front-end loader moves the snow into a collector.

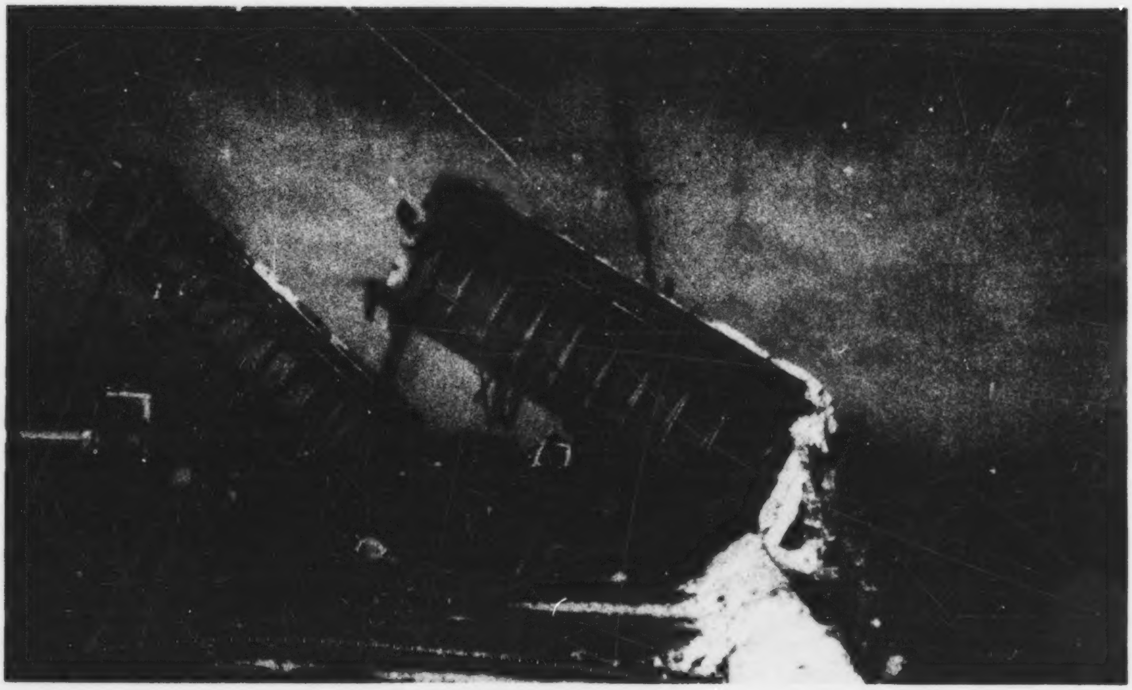
4.3.3 **Operating costs.** The operating cost for sewer chute disposal is \$0.11 per cubic metre, broken down as follows:

- manpower (68%)
- equipment (30%)
- miscellaneous services (2%)

4.4 **River Dumping.** The city uses four river dump sites for its snow disposal operations. River dumping accounts for 31 percent of all snow disposed of in Montréal.

4.4.1 **Treatment.** Here too, the treatment process is straightforward. The snow hauled by truck is dumped directly into the St. Lawrence. The dump sites are the Concorde Bridge and piers 30, 52 and 74. Each year, a total of 1.3 million cubic metres is dumped at the Concorde Bridge and Pier 30, 537 000 cubic metres at Pier 52 and 110 000 cubic metres at Pier 74.

4.4.2 **Environmental considerations.** Talks between representatives of the Québec Department of the Environment and the City of Montreal concluded that the city should



River dumping: snow is hauled directly to the St. Lawrence

be given special status because of its proximity to the St. Lawrence and the negative impact strict river dumping regulations would have on the city's economy.

Despite the exempt status, the city makes every effort to minimize the possible environmental damage caused by river dumping. In fact, the city has virtually eliminated three of the major problems that MENVIQ has associated with river dumping.

For one thing, the department of public works chose its dump sites at points where the river current is sufficiently strong to prevent possible flooding or obstruction.

The city has also avoided the risk of bank erosion by using the Concorde Bridge and Montréal Harbour piers as dump sites; in no way are the banks of the St. Lawrence affected by dumping. As for possible river pollution, we should point out that, unlike smaller watercourses where problems could occur, the waters of the St. Lawrence can easily handle snow disposal. Current data show the volume ratio of waste snow to river water as 1:10 000.

However, since the question of river dumping and pollution has yet to be fully resolved, the City of Montréal, in its concern to preserve the river as a natural resource, has agreed to study the issue further. It has commissioned the centre for technology

Quarry dumping: the Francon quarry

development at the École polytechnique to carry out an in-depth study on the ecological impact of snow disposal in the St. Lawrence at the Montréal Harbour.

The city expects to have the study's final report sometime in 1985. Its recommendations will no doubt provide Montréal with all the information needed to give the city's overall snow disposal policy a clear direction with both short- and medium-term solutions, if required.

4.4.3 **Operating costs.** The department of public works has determined that river dumping is the least expensive of all the methods now used, a mere $0.10 per cubic metre.

At the Concorde Bridge site, the cost breakdown is 74 percent for manpower, 23 percent for equipment, and 3 percent for miscellaneous services. For the three pier sites, the breakdown is 48 percent for manpower, 14 percent for equipment, and 30 percent for miscellaneous services.

4.5 **Quarry Dumping.** In its continual search for new and environmentally safe snow disposal methods, the City of Montréal has come up with a unique and ingenious solution---quarry dumping.

Almost three years of study went into developing this new method. Every aspect, from site capacity and drainage to site development, security and traffic, was painstakingly analyzed. The city spent a total of $23 million to purchase and develop the Francon quarry site for snow disposal. Since the winter of 1981-82, the city has been able to dispose of 25 percent of all its waste snow at this site.

4.5.1 **Treatment.** Waste snow is dumped into the quarry from the rim above; the accumulated snow needs no further treatment. The first stage of the site's development took place in 1981 with the construction of ten unloading docks, each with a capacity of about 110 000 m^3. In 1982, three overhanging docks, with a capacity of some 150 000 m^3 each, were added to allow maximum accumulation underneath.

4.5.2 **Environmental considerations.** The public works department had first thought that a water retention basin would improve the heat exchange between the snow and surrounding area. Because of the possible problems caused by the stagnant water, however, the department decided to use a pumping station to send the meltwater into the municipal sewer system and eventually on to the treatment plant.

As with other methods, site security is assured by such facilities as an adequate lighting system, fences and control huts.

The volume of heavy-vehicle traffic in the city's north sector is the most serious problem faced by the department with this particular method. After a snowstorm, as many as 250 or more trucks may be used to haul snow to the quarry at all hours, severely congesting the only two access roads to the site.

The city is now studying the possibility of opening new access roads to the site in order to clear up traffic congestion on Pius IX and St. Michel Boulevards as much as possible. The city will also take steps to deal with the inconvenience to nearby residents caused by the noise levels at the quarry site. We should stress, however, that much of the area around the quarry is used for commercial or industrial purposes.

4.5.3 **Operating costs.** The current cost of operating the snow disposal site at the Francon quarry is $0.17/$m^3$, broken down as follows: 37 percent for manpower, 32 percent for equipment, and 31 percent for miscellaneous services.

Snow disposal in a city like Montréal is obviously an important activity, and one that must be carefully regulated. It is the city's responsibility to provide its residents with a fast, safe and efficient snow disposal service at little or no risk to the environment.

5. Prospects for the Future

Although Montréal is satisfied so far with the efficiency, effectiveness and environmental safety of its various snow disposal methods, it is still looking for new techniques and ways of improving existing ones.

For the time being, the city is not planning to use all four of its snow melters because of their high operating costs. If this becomes necessary, however, it will want to study other ways of powering them (electricity, natural gas, solar power, and so on), since the use of melters has proven to be a very environmentally safe method.

As for snow disposal in sewers, the water treatment department of the Montréal Urban Community, in cooperation with MUC municipalities, is studying the feasibility of increasing the disposal capacity of municipal collectors and interceptors. Other steps to be taken in this area include construction of an additional interceptor (expected to be operational by 1990), changes in current procedures to allow better use of wastewater heat, and a management program designed to maximize the disposal capacity of these facilities. All of these improvements, however, will require maintaining conditions that are within the capability of the water treatment facility at Rivière-des-Prairies. This year, the public works department is already going ahead with plans to enlarge some of the city's snow removal zones which, among other things, will increase truck loading periods and help to extend sewer disposal operations over a longer period of time.

In addition, the department recently completed a feasibility study on increasing the Francon quarry's disposal capacity from 2 to 5 million cubic metres. The expansion would require building nine new unloading docks, excavating the rock walls and floor on the quarry's east side, modifying the existing docks, and rebuilding both the retention basin and pump station. The total cost is estimated at between $20 and $25 million.

As for piling snow along roadways, the method preferred by MENVIQ, it is our opinion that such a method is incompatible with Montréal's urban environment and the very nature of its street and road network.

The main purpose of improving our snow disposal methods is to lower the overall cost of snow removal and disposal. In 1983, Montréal taxpayers paid $42 million for this service. The thousands of suburban residents who used Montréal's streets and roads each day also benefitted from this well-organized operation.

It is always easy to demand more and more. What we must keep in mind, however, is that the economic consequences of technical solutions can be as important as the environmental impact these solutions will have.

6. Conclusion

As has been made clear throughout this report, the City of Montréal has based its snow disposal program on principles that are compatible with a healthy environment; each of the methods used respects those principles.

Nevertheless, for a city like Montréal, with its harsh winters, high population density, and extensive road network, it has been a challenge to maintain this policy. The city administration and its public works department believe they have successfully met that challenge.

Montréal now believes it can offer its residents a fast, safe, and effective snow disposal service worthy of a modern metropolitan center. This ability, however, depends on the judicious use of several different methods in combination. If strict regulation forced the city to abandon or even modify any one of these methods, for example, the consequences could be quite difficult indeed to offset.

The City of Montréal is convinced that, given the physical, geographic, economic, and environmental factors involved, its snow disposal methods are the most appropriate. It nevertheless wants to continue playing a leading role in this area and is willing to consider any and all new methods or techniques to continue to provide the best service it can with the least amount of damage to the environment and at the least cost to the taxpayer.

Appendix (Excerpt from report entitled, "Operating Costs of Snow Disposal Sites - Montreal - Winter 1981-82")

The unit operating costs for each of the various disposal sites were based, on the one hand, on manpower and equipment, nondurable goods, miscellaneous services, and site rental; and on the other hand, the volume of snow hauled.

1.0 **Volume of Snow Hauled.** The total volume of snow hauled during the winter of 1981-82 was 8 214 740 cubic metres. A relationship between snowfall and the volume hauled was developed. Table 1 shows the recent range of values.

1.1 During the winters of 1978-79 and 1976-77, the snow haulage figures were about the same (between 8.2 and 8.5 million cubic metres) while the snowfall equalled

TABLE 1 TOTAL VOLUME OF SNOW HAULED WITHIN MONTRÉAL CITY LIMITS (based on total equivalent snowfall)

Winter	Total Equivalent Snowfall (cm)		Volume of Snow Hauled (m^3)
	Dorval	Montreal	
1970-71	345.7	439.9*	17 289 205
1971-72	258.8	325.9*	12 016 826
1972-73	242.6	-	9 430 635
1973-74	190.2	-	4 845 310
1974-75	198.1	-	9 317 521
1975-76	272.9	-	9 315 780
1976-77	189.7	-	8 163 374
1977-78	203.6	-	12 281 645
1978-79	196.4	211.0**	8 475 358
1979-80	87.5	84.8**	-0-
1980-81	129.0	123.4**	-0-
1981-82	208.2	239.6**	8 214 740

* McGill
** Montreal Triangle

between 190 and 195 cm. In 1977-78, however, although the precipitation was about the same, the amount of snow hauled was more than 12 million cubic metres. These figures are from readings taken at Dorval since the Montreal Station did not exist prior to 1978.

1.2 **Comparision of monthly snow haulage percentages with monthly snowfall percentages.** A comparison of monthly snow haulage figures for the winter of 1981-82 shows that no snow was hauled in November and that 50 percent of the total haulage was carried out in December and January. As compared to monthly snowfall accumulations, there is a significant difference between the percentage of snow hauled in December and January (50%) and the percentages of total snowfall during those months (66%). The loading schedule cannot account for this 16 percent difference. February was the busiest month for snow haulage.

1.3 **Volume of snow hauled ot the various disposal sites.** A breakdown of volume of snow hauled to the various snow disposal sites shows that 30.4 percent of all snow collected within the City of Montréal was disposed of in the St. Lawrence River, 26.2 percent at land dumps, 23.2 percent at the Francon quarry, and 20.2 percent in sewer chutes.

1.4 Average truckload volume. The average truckload volume presented in Table 2 was calculated for the east and west regions; the north region was not able to provide appropriate data.

TABLE 2 AVERAGE TRUCKLOAD VOLUMES

Region	Division	Average Truckload Volume (m^3)
West	West	23.79
	Centre	26.05
	Overall	24.32
East	East	26.12
	South	19.07
	Overall	23.29
North	North	-0-
	North-Centre	-0-
	Overall	-0-
	CITY	23.73

On the basis of these figures, the total number of truckloads hauling snow to the city's various disposal sites is 351 927, or 4 240 trips for an average zone containing 20 000 metres of roadway. Based on the monthly breakdown of snow hauled by region, the number of truckloads by month is shown in Table 3.

TABLE 3 NUMBER OF TRUCKLOADS BY MONTH

Month	Monthly % of Snow Hauled	Number of Trips
November	-0-	-0-
December	21.37	906
January	29.00	1 230
February	6.82	1 561
March	12.81	543
	TOTAL	4 240

2.0 **Operating Costs.** The operating costs of the 22 snow disposal sites used during winter 1981-82 were based on manpower, equipment, nondurable goods, miscellaneous services, and rental as well as the volume of snow hauled to each site.

2.1 **Average unit costs of the various types of disposal site.** The average unit cost figures for operating the various types of disposal sites contained no surprises. The one exeption was the unit cost for operating land dump sites, which reached \$0.37/m^3; a cost of \$0.26/m^3 was expected in view of the new methods developed for operating these sites. We had forecast a cost of \$0.14/m^3 for the Francon quarry; the cost calculated by this study came to \$0.15/m^3. The operating cost for sewer chutes came to \$0.09/m^3, 10 percent higher than had been estimated. Finally, the operating cost of river dump sites came to \$0.08/m^3, 30 percent more than our forecasts. Table 5 shows the unit operating cost for each disposal site, as well as the volume of snow hauled; a weighted average can be taken of these figures. A review of the variations in these unit costs follows.

2.2 **Variation in unit operating costs over time.** The variation in unit operating costs for the varioius disposal sites since winter 1971-72 is shown in Table 6. Although these unit costs have increased over the years, the closing down of the melters and the use of the Francon quarry have brought down the weighted average cost of snow disposal in Montreal. This decrease was 10 percent over the cost in 1978-79. Consequently, it cost less to operate the city's disposal sites in winter 1981-82 than in previous years. The last time this weighted cost was as low was in 1974-75.

2.3 **Francon Quarry.** The cost of operating Francon quarry was \$0.15/m^3, made up of hydrocosts (\$35 922) and pump maintenance costs (\$57 426). This figure obviously respresents and average cost for the various types of disposal site since some 1 100 000 m^3 of snow was dumped from the site's ten unloading docks, plus another 800 000 m^3 dumped around the site or on the quarry floor. Since disposal of this snow was accomplished at a unit cost lower than the cost for land sites, the operation has to be considered a success.

2.4 **Sewer Chutes.** The cost of operating sewer chutes can vary greatly from one site to another; in this case, from \$0.0377 to \$0.02262 per cubic metre. Analysis of the cost variations involved, based on the total volume of snow dumped at each chute, suggests a zone within which operating costs appear normal. The Iberville, Dickson, and De l'Épée chutes show costs that are too high. It should be pointed out, however, that there are not front-end loaders operating at the Anbar and St. Pierre sites in February and

TABLE 5 OPERATING COSTS OF DIFFERENT DISPOSAL SITES

Type of Site		Site Name Unit Cost (UC) Volume of Snow (VOL) Hauled (m^3)				Average Unit Cost	Snow Hauled (m^3)
Quarry	Name				**Francon**		
	UC				$0.1540		
	VOL				1 937 100	**$0.1540**	**1 937 100**
Chutes	**Name**	**Papineau**	**Sauve**	**Bruchesi**	**M. Wilson**		
	UC	$0.0758	$0.0728	$0.0953	$0.0983		
	VOL	149 281	220 420	164 002	59 950		
	Name	**De l'Epee**	**Dickson**	**St. Pierre**	**Anbar**		
	UC	$0.2262	$0.2009	$0.0377	$0.0498		
	VOL	102 918	193 813	6[illegible]8 598	209 901		
	Name	**Iberville**					
	UC	$0.1607					
	VOL	86 100				**$0.0912**	**1 684 883**
Land	**Name**	**Irwin**	**Royalmount**	**Beaubien**	**Contrecoeur**		
	UC	$0.2769	$0.2941	$0.5617	$0.3888		
	VOL	204 520	607 437	530 136	244 502		
	Name	**P. Bernard**	**Marco Polo**	**68e Ave**	**S/M. Duplessis**		
	UC	$0.2137	$0.3751	$0.5355	$0.4354		
	VOL	241 656	195 658	39 243	8 572		
	Name	**Hamon**					
		$0.2429					
		118,380				**$0.3682**	**2 192 104**
River	**Name**	**Pier 52**	**Concorde**	**Pier 30**			
	UC	$0.1026	$0.0809	$0.0779			
	VOL	570 085	695 953	1 271 065		**$0.0843**	**2 537 104**

TABLE 6 OPERATING COST PER CUBIC METRE FOR SNOW DISPOSAL FROM 1971-72 TO 1981-82

	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1981-82
Land Sites	$0.087	$0.101	$0.117	$0.132	$0.162	$0.173	$0.250	$0.230	$0.370
Sewer Chutes	$0.049	0.062	0.095	0.067	0.088	0.098	0.050	0.060	0.090
Melters	0.387	0.502	0.498	0.601	0.851	0.701	0.620	0.800	1.750*
River	0.021	0.033	0.043	0.043	0.047	0.051	0.040	0.040	0.080
Quarry	-	-	-	-	-	-	-	-	-
WEIGHTED AVERAGE	0.110	0.132	0.155	0.167	0.099	0.195	0.200	0.190	0.180

* Estimated

March. An examination of the monthly operating costs show excessively large variations for the same sites. Therefore, a number of site management problems must exist.

2.5 **Land Disposal Sites.** The costs of operating land disposal sites can also vary quite significantly, in this case, between $0.2127 and $0.5617 per cubic metre.

2.6 **River Dump Sites.** Unlike sewer chute and land disposal sites, river dump sites show much less variation in operating cost; in this case, from $0.0779 to $0.1026.

The variation in operating costs for the various sites, on the basis of total volume of snow dumped, is normal. Furthermore, there is little variation in the monthly cost figures which indicates proper site management.

3.0 **Analysis of Operating Costs.** Analysis of operating costs could be taken a step further by checking the work periods of personnel assigned to the various tasks involved and comparing them with the normal hours of site operation or disposal periods. With not enough time and data, however, we can only indicate the breakdown of manpower costs in relation to equipment cost, on the basis of costs for nondurable goods, miscellaneous services, and site rental.

The total cost of snow disposal was $1 473 577, compared with the 1981 budget forecast of $1 413 800 and the 1982 forecast of $1 568 100.

3.1 **Variation in manpower and equipment costs according to site.** Table 7 shows a breakdown of average costs according to site.

An interesting finding is that for land sites and sewer chutes, the manpower and equipment costs are reversed. For river disposal, the main difference between the Concorde Bridge and the piers is in the costs for miscellaneous services (site preparation and repair costs). For the Francon quarry site, the three cost categories are about equal.

TABLE 7 AVERAGE COST PER SITE

Sites	Manpower %	Equipment %	Miscellaneous Service %
Land	29.3	68.1	2.6
Chutes*	68.4	30.2	1.4
River			
Pier	47.6	14.3	38.1
Bridge	74.3	22.5	3.2
Francon	37.3	31.4	31.3

* Anbar not included.

On the whole, the breakdown of manpower, equipment, and miscellaneous service costs for the land sites is respected, as is true for the chutes as well. Except for the St. Pierre, Anbar, and Suave chute sites, and for the river sites as well, the differences stem from the costs for miscellaneous services.

3.2 Comparing breakdowns of volume of snow hauled to sites with breakdowns of operating costs for same sites. What is quite evident from this comparison is that snow disposal at land sites costs more than double the normal cost, while sewer chutes and river disposal cost about half. Quarry disposal represents a normal operating cost. The elimination of land sites in favour of other types of disposal, therefore, is an important consideration.

Conclusions and Recommendations

The average unit operating costs for the various types of snow disposal sites are as follows:

	per m^3
Francon Quarry	$0.15
Sewer Chutes	0.09
Land Disposal Sites	0.37
River	0.08
Melters	1.71*

* Estimated Cost

The operating costs for land sites and sewer chutes vary a great deal. Research into the allocation of snow disposal sites with the aid of the PAFCDN program should be undertaken with real costs. For analysis of tenders, average indexed costs can be used. As for the setting of snow disposal costs for private contractors, fringe benefits, and administrative costs would have to be added to manpower costs.

According to our data, a total of 136 450 m^3 of snow was disposed of at the various sites by either private contractors or our employees responsible for snow removal in parking lots, parks, and alleys. This volume should be significantly larger, about 300 000 m^3. This particular situation deserves special attention since it is important to maintain a balanced sharing of snow disposal operations.

To ensure proper management of disposal sites, data should be furnished on a monthly basis and analyzed as soon as possible. Further analyses could then be carried out.

QUESTIONS AND ANSWERS

Question: I would like to know about the snow that is poured into the river. Are there any procedures to ensure that it is more or less clean snow? Is the snow poured in there within 48 hours of a snowfall, or is it just any old snow?

Response: There is no actual snow selection. The overall snowfall of a neighborhood is transported and dumped into the river. It is just about impossible to consider what you are suggesting because of the time constraints that we have to remove the snow.

Question: In Montréal, where is snow disposed of from private property such as parking lots?

Response: We supply the space for the snow that comes from private enterprises. Disposers pay to obtain access to our dumps. The volume involved is a small percentage of what the city must dispose of. What we see is that a gas station or an operation like that tries to get along with our foreman. Along side streets they push a little snow along the street and we pick it up. So although there is a pile on the private side, we know for a fact that we may have picked up 50 percent of the snow. Also, we do get the snow from the major provincial highways in the area.

ENVIRONMENTAL EFFECTS OF SNOW DISPOSAL IN SWEDEN

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Snow Handling

During a normal winter the snow cover lasts only 36-40 days in southern Sweden but up to 250 days in the northern mountain regions. There are also large variations in the annual amounts of snow in Sweden. These variations affect the way of snow handling in the urban areas. In the south, with infrequent snowfalls and a comparatively mild climate, spreading of salt is dominant. In the north, the streets are most often plowed and sanded. As a rule, the order of plowing, after a snowfall, is the following:

- Pedestrian and bicycle streets
- Major thoroughfares
- Bus routes
- Other streets

The plowing normally starts when the snow depth has reached a given level, say 3-8 cm. After the snow clearance, the snow from some of the streets is transported to snow dumps outside the urban areas. The main reason for this transportation is that there must be areas available for storing the next snowfall. Accordingly, the choice of streets from which to transport snow is made for practical rather than for environmental reasons.

There is a clear tendency found, for economic reasons, that the amount of snow transported to snow dumps is decreasing. Transport of snow is a very costly undertaking and the crews and lorries are often hired by the hour. Thus, today, the snow remains longer along the streets.

The snow transported away from the streets may be dumped either at a snow dump, such as an open field, or into a watercourse. No legislation is applicable to snow dumping in Sweden today.

Pollutants in Urban Snow

Urban snow and melting snow are clearly more polluted than storm water runoff. The concentrations of pollutants depend on the pollutant sources, for how long and where the snow has been deposited, and how the snow has been handled.

Some pollutant sources are more important in the winter than in the summer. Air pollution is worse in the winter because of heating. Concentrations of sulphur dioxide and soot in the atmosphere, for example, have been shown in many studies to be considerably higher in the winter. The corrosion of building metals is also increased. Automobile exhaust causes more pollution in the winter because of increased idling time and the use of the choke. Pavement wear increases greatly because of the use of studded tires. Salt and sand are spread on the streets. Corrosion of cars, road marking, and rails increases.

Falling snow may have higher concentrations of pollutants than rain, at least at the beginning of a precipitation event. Gjessing and Gjessing (1975) have demonstrated that snow flakes, because of their larger specific area and lower settling rate are more able to absorb pollutants from the atmosphere than raindrops.

Snow contamination depends to a large extent on how long the snow has been lying on the ground. Pollutants accumulate effectively in snow, which acts as a mechanical filter for fine particles in the air. Snow that has been lying long in an urban area may contain considerable amounts of pollutants, especially if it has accumulated steadily, with no melting periods. Accumulation of pollutants in snow was investigated by Doyland and Hansen (1975) in an area in Oslo, Norway. Over a period of ten days the concentration of sulphate in untouched snow more than doubled, and the concentration of lead more than tripled. The accumulation of heavy metals in snow was also studied by Lisper (1974) near a highway in Goteborg, Sweden. Results from this study are presented in Figure 1 (Malmquist, 1978).

The quality of urban snow was studied in areas with different land use in Goteborg, Sweden (Malmquist, 1978). Samples of untouched snow on grassy surfaces and of snow from the piles alongside streets near the grassy surfaces studied were taken. Sampling was carried out in early March, and about ten days had elapsed since the previous snowfall. The concentrations of some substances in snow are presented in Table 1 (Malmquist, 1978).

From the sample it can be seen that the concentration of pollutants in snow from streets were on the average 10 times higher than in snow from grassy surfaces. The snow from streets was, moreover, roughly five times more polluted than average storm water from the studied areas.

Pollutant concentrations in snow on rooftops and along a highway have been studied in Vastergotland, a province in midwestern Sweden (Malmquist and Hard, 1981).

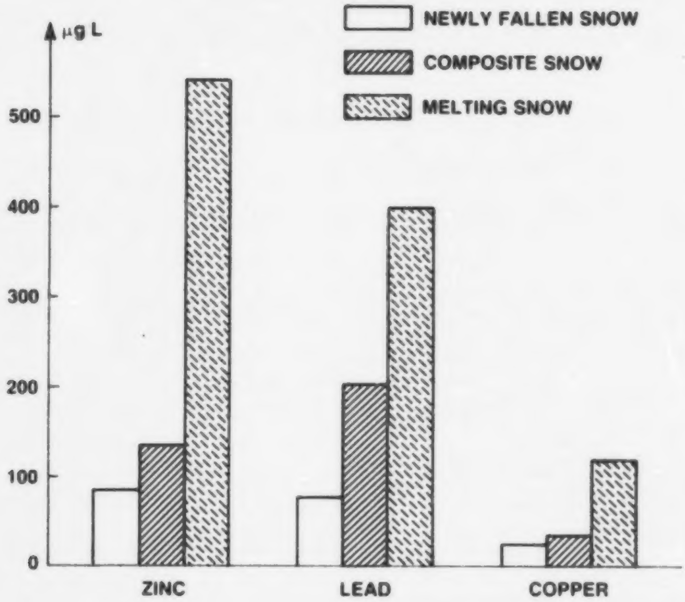

FIGURE 1 HEAVY METALS IN DIFFERENT TYPES OF SNOW NEAR A HIGHWAY IN GOTEBORG, SWEDEN (Malmquist, 1978)

TABLE 1 CONCENTRATION OF POLLUTANTS IN URBAN SNOW IN GOTEBORG, SWEDEN (Malmquist, 1978)

Population Density/ha	Sampling Site	COD mg/L	P_{tot} mg/L	N_{tot} mg/L	SO_4 mg/L	Pb g/L	Zn g/L	Cu g/L
250	Grass surfaces	80	0.41	1.70	< 5	250	360	50
250	Street, 7400 veh/day	850	2.10	3.60	19.3	2610	1030	390
115	Grass surface	30	0.11	1.20	< 5	40	50	10
115	Street, 3600 veh/day	260	0.54	1.30	7.5	730	330	70
22	Grass surfaces	10	0.09	0.82	< 5	40	60	10
22	Street, 1500 veh/day	260	1.63	1.60	5.5	730	330	120

The results indicated that snow on rooftops was far less polluted than snow from along highways, especially with regard to suspended solids, iron, chemical oxygen demand (COD), lead and cadmium. Differences in atmospheric fallout were also found. The variations in the results were large, because there had been both snowfall and snowmelting in the period between the sampling occasions. The results presented in Table 2 are average values of three samples (or two samples for the residential area).

From the studies reported and from other studies in Sweden it may be concluded that:

- The lead concentration in snow alongside streets may reach levels up to some mg/L.
- The concentration of copper may reach levels of about 0.5 mg/L.
- The concentration of cadmium varies normally from 0.0001-0.01 mg/L.
- The concentration of chloride varies considerably because of the spreading of salt but may reach levels of some µg/L.

It may be generally concluded that:

- Snow alongside or near streets or highways is much more polluted than snow on grass of on rooftops.
- The snow becomes more polluted the longer it lies on the ground.

TABLE 2 POLLUTANT CONCENTRATIONS IN SNOW FROM ROOFTOPS AND A HIGHWAY IN VASTERGOTLAND, SWEDEN (Malmquist and Hard, 1981)

		Rooftops				Highway-grass median	
		Residential		Industrial			
Components		Max.	Mean	Max.	Mean	Max.	Mean
Suspended solids	mg/L	62	40	43	22	7200	3800
COD	mg/L	26	20	66	43	3700	2200
P tot	mg/L	0.17	0.11	0.14	0.081	1.3	1.0
PO_4-P	mg/L	0.077	0.064	0.033	0.024	0.98	0.71
NO_3-N	mg/L	4.0	2.3	3.0	1.7	1.5	0.88
Kjeldahl-N	mg/L	0.62	0.50	4.9	2.1	7.0	3.2
NH_4-N	mg/L	0.43	0.37	0.52	0.37	0.44	0.26
Fe	mg/L	0.55	0.49	0.96	0.61	60	45
Pb	µg/L	31	29	19	10	3100	1700
Zn	µg/L	49	44	230	120	490	250
Cu	µg/L	9	9	4	4	320	170
Cd	µg/L	0.6	-	0.3	-	12	4.9

The conclusions are confirmed by other studies in Sweden (summarized by Malmquist, 1980) and elsewhere.

The concentrations of pollutants in the snow at snow dumps have been investigated at some 20 locations in Sweden, mostly using grab samples. The concentrations were found to range within the following values:

COD: 22-900 mg/L
Pb: 0.04-2.5 mg/L
Cd: 0.01-0.03 mg/L
Cu: 0.02-0.27 mg/L
Cl: 3-1500 mg/L

There is a clear tendency indicating that snow in dumps that receive snow from industrial or trafficked areas show much higher concentrations than snow in other dumps.

Environmental Effects

During snow melting periods, the pollutants in the snow are transported faster than water, which means that the first part of the melting snow contains considerably higher concentrations of pollutants than the snow itself. This phenomena has been proven both in laboratory and field experiments, and was true for all of the 14 substances studied (H^+, sulphate, nitrate, chloride, heavy metals).

The melting snow either infiltrates the ground or runs off on the surface. Melting snow from piles in the streets runs off into the storm water system. The environmental effects of this runoff are the same as from a storm water runoff during rainfall, except that the concentrations of pollutants may be higher.

The melting water from a snow dump infiltrates the ground if the melting/runoff intensity does not exceed the infiltration capacity of the ground. Except for when the soil is hard clay, or when the ground is frozen, generally all water from a snow dump should be able to infiltrate the ground. The extent to which the ground under a snow dump freezes is not well known today. If the height of the snow dump is not too great in relation to the air temperature, the ground remains frozen during the snowy season, and thaws from the top during snow melting. If the snow dump is high the ground will thaw from below because of the heat flow from the earth. Other factors that affect snow melt are the degree of pollution of the snow (the albedo), the degree of compacting, the time of year, etc. No measurements of melting at snow dumps or of the thawing and the infiltration capacity of the ground under snow dumps have been carried out.

Effects on Groundwater and Soil

The melting snow affects the soil and the groundwater when it infiltrates the ground. However, investigations of the soil under snow dumps have not to date revealed any increased concentrations of pollutants in the soil, possibly because of the low infiltration capacity of the frozen topsoil.

The impact on groundwater has been proven by analysis of the groundwater downstream of percolation basins (recharge basins) for storm water runoff and of groundwater that has been infiltrated in ditches alongside highways (Anderson et al., 1979; Malmquist and Hard, 1981). During a period of ten years, at least some 40 cases have been reported in which water wells have been abandoned due to increased concentrations of chloride from the salting of highways. However, some of these cases are attributable to leakage of salt from salt storage areas.

Sodium and chloride have also been reported to have caused the death of pine trees alongside highways where salt has been spread.

Effects on Surface Waters

Melting snow and snow dumped directly into a watercourse may affect water quality in a number of ways. High concentrations of heavy metals may be a serious factor, in combination with the low pH-values which occur early in a melting period. Oxygen deficits and aesthetic effects are other serious factors affecting the surface waters. There have been only a few studies of the effects of melting snow on surface water in Sweden, and no clear relationships have been established.

Discussion

The total amounts of pollutants from an urban area during a winter season are largely the same, regardless of whether it rains or snows, or how the snow is cleared and transported. What happens is that the receiving water may change when the snow is transported - from one watercourse to another, or from the normal storm water receiving water to the groundwater. Therefore, the potential and requirements of the receiving water should be carefully studied and the results should be used as a guideline for the planning of snow clearance in the urban area.

The National Swedish Environmental Protection Board is now considering recommending that the snow in an urban area be studied with respect to its concentrations of pollutants.

Melting snow from grassy surfaces or other untouched areas has relatively low concentrations of most pollutants (although the pH may be low), and may be infiltrated naturally into the ground or transported by the normal storm water system.

Snow that has fallen on traffic areas and has been cleared shortly after the snowfall also has relatively low concentrations of most pollutants and may be dumped on any land tip or into a watercourse, where it will cause no more damage than a storm water runoff during rainfall. However, the possible aestheic effects must be taken into consideration. Snow left to lie for more than one day on streets or alongside streets accumulates considerable amounts of pollutants. When melting snow from such areas runs off to receiving water or infiltrates the ground, the effects may be serious. It is important to select a proper body of receiving water for this snow. Dumping into a watercourse should generally be avoided.

If the snow is dumped on a land tip, this tip should be located, planned and operated in the same way as a sanitary landfill. Infiltration of the melting snow may be allowed on the same conditions as for the infiltration of wastewater or storm water. The recommendations from the Environmental Protection Board are, provisionally:

1. Snow that is cleared immediately after a snowfall may be deposited on an unrestricted basis.
2. Snow that has been left to lie on heavily trafficked streets should not be deposited on farmland or upstream of groundwater wells. Dumping of such snow into a watercourse is not recommended. The melting snow from a land tip must not run off into sensitive or acidified receiving waters.
3. Melting snow with very high concentrations of pollutants (no quantifications have, as yet, been made) should be treated at sewage treatment plants.

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QUESTIONS AND ANSWERS

Question: Could you be more specific on the number of days mentioned that we delay pickup of the snow if we want to dispose of it in watercourses or put it on open land?

Response: I am sorry I cannot. That has not yet been decided. They are talking about a couple of days, but the exact number has not been decided.

Question: But you are talking about only a couple of days?

Response: That is right. Basically, we are trying to distinguish between heavily trafficked streets and others, and we are saying that the more polluted snow should be treated one way and other snow would be treated slightly differently.

Question: Did you indicate that the snow that is left in windrows on the side of the streets almost acts as a sieve or a collector for pollutants and increases over time?

Response: That is right.

Question: If this snow is on or inside the curb, then as the melting period comes it will go into, as we have in North America, the street drainage system to a storm sewer system and into the watercourse. Therefore, the runoff will be heavily polluted and will run directly into the streams. This morning the Province of Québec indicated that the preferred method was to leave the windrows which collect pollutants and increase the chance that pollutants will get into the streams. Is that correct?

Response: Yes, that is right, I think, provided that the receiving water for the urban storm water runoff is selected properly.

Question: It is not selected, it is an existing system. I am saying that we are dealing with an existing infrastructure, storm water system, and how to manage snow disposal. If we leave it at the side of the road as the first recommended procedure in the Province of Québec draft paper, you would end up with the most contaminants reaching the receiving waters, if I understood your presentation.

Response: Yes, but I think if the receiving water can take heavily polluted storm water runoff, it can also take the snow melting. The worst case is if you move this polluted snow into another watercourse that cannot take this pollutant load, assuming that you have a choice.

Question: If you had a choice of picking up the snow and putting it into a faster running river, or one with greater volume, then that would be the preferred course?

Response: That would be better, yes.

Question: In the case of the City of Montréal, moving snow from one of the smaller streams to the St. Lawrence River would be preferable?

Response: I dare not say. I do not know what I am getting involved in.

Question: It is better to remove snow into a bigger flow of river than a smaller?

Response: Yes.

Question: Your diagrams indicated the intent to have infiltration of the flow from near the place from where it was generated. Does this include the snowmelt and if so, at what depth are the infiltration galleries so that they are not affected by the frost and frozen ground?

Response: They are below the limit of frozen ground, say one or two metres below ground. Meltwater from rooftops and grass areas, and from streets when it is applicable, is the preferred plan. It is quite a common technique in Sweden today. We are planning new urban storm sewer systems to include the possibility of infiltrating storm water.

Question: Your values of zinc seem much higher than what I have experienced or at least the values I've seen in Ontario. Are you aware of any explanation or something different in Sweden that would lead to higher zinc values?

Response: Do you mean the average values or the variation or both?

Question: I thought that average values were presented.

Response: The study we made was in a couple of areas. We have reported from that study quite high concentrations of zinc and copper. The high concentrations depend on the building materials. We use copper as roofing plates and we use galvanized steel for downpipes and lamp posts to a great extent. In my thesis, as a matter of fact, I am studying those things and I can tell how much comes from each place and under what circumstances. I am quite certain from where it comes.

Question: Did you have a chance to filter your snow or determine what was soluble and what was insoluble? Or was this straight?

Response: Yes, we did filter the samples. I do not have figures with me, but I am certain that the figures were not very different from what you may expect to find in urban storm water, for instance. Lead was almost exclusively particulate and zinc a little less and copper definitely less particulate than lead. But I have no figures with me.

Question: You indicated that the discharge of the initial flush should not go to acidified lakes. We had a discussion this afternoon with regard to acids, now acid precipitation or acid rain. I just wonder if there have been any variations that have been noticed in Sweden? It sounds as if we are reaching the state of acidification that you reached a few years ahead of us. We are just looking at what possible changes we might anticipate in the results here and what we should or should not be doing in terms of controlling the snowmelt.

Response: We have made some studies in Sweden on what we call acid shock in rivers, and it is clearly proven that this phenomenon exists. You get acid shock even in large rivers during the melting period.

Question: You also showed much higher concentrations of the heavy metals in the first initial flush, which dropped off rapidly. I wonder if over a period of time this concentration factor has increased or decreased or remained the same.

Response: I cannot say that I know that. But I know that this concentration factor is even larger in the field than in the laboratory investigations. The effect is produced by nature in some way.

Question: What is the policy in Sweden concerning lead-free gasoline? Do you use very much lead-free or is it all leaded?

Response: A few years ago we used 0.4 grams of lead per litre, and two or three years ago it was decreased to 0.15 grams per litre. Discussions are going on to decrease it further. We know from where lead comes and we are going to do something about it. The reason we have not moved faster is the difficulty in obtaining legislative action which might hurt commerce. We couldn't do it on our own. We export cars to the United States which are equipped for unleaded gasoline, but you cannot drive or buy them in Sweden because it is against the rules of the common market.

Question: Am I correct in assuming that your forced infiltration practices do not result in serious sodium and chloride contamination of groundwater?

Response: Yes, since they are quite soluble they will pass through and contaminate the groundwater. So you should not pick infiltration sites that have drinking water wells downstream. We have made many studies on the other contaminants in infiltrated water and they all show that the contaminants stay on the surface if you have surface infiltration or in the percolation basin if you use a static stream. It has been quite an effective technique to stop the pollutants for a time anyway. But we have also made some estimations as to how long they will stay there because the basin will eventually get full of what is infiltrated. Different methods take different times to get contaminants circulated. For some it will take at least one thousand to several thousand years before they get into a solution again. The worst case was zinc which will be recirculated in only a few hundred years.

SULPHER AND HEAVY METAL POLLUTION OF URBAN SNOW AND THE ENVIRONMENTAL IMPACT

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It is generally perceived today that one of the most important and vexing challenges in the field of public health is the proper investigation and subsequent control of air, water and soil pollution in industrialized urban cities and rural areas. Over the last several years it has become increasingly clear that substances released into the air by various industrial plants and automobile exhaust can produce adverse physiological changes in man. Furthermore, polluting substances released to the environment can have important toxicological effects on aquatic, animal, and plant ecosystems. Airborne pollutants of concern include oxides of nitrogen and sulphur, photochemical oxidants, synthetic compounds, fine particulates, and trace metals. These substances can, and do undergo long-range transport through the atmosphere. A primary pathway back to earth is by means of precipitation, both wet and dry, often at distances hundreds to thousands of kilometres downwind from the original sources.

Among recent environmental studies the measurement of trace elements, in fine particulates and in wet atmospheric depositions, has received increased attention because of their potential toxic effects (Ronneau and Hallet, 1981; Tanaka, Darzi, and Winchester, 1981; Rohbock et al., 1981; Lindberg, 1981; Thornton et al, 1981; Hamilton and Chatt, 1982; Jeffries and Snyder, 1981; Landsberger et al., 1982; Landsberger et al., 1982; Jervis et al., 1982; and Landsberger et al., 1983).

In general terms, the study of elemental toxicity can be considered to fall into four main aspects. The first aspect, the most immediately important, is related to the environmental occurrence. A second consideration is the physical and chemical state of the pollutant. It is evident that the toxicity of the specific element can be influenced by either its chemical composition (pH, choice of anion, solubility, and stability) and/or physical characteristics (particle size and method of formulation). The next important aspect is the identification of the major routes of entry into the human body. This is often dependent on the physical and chemical characteristics of the element in question. A fourth factor is the metabolic fate and toxicological consequences of the xenobiotics.

An overall view of environmental and human pathways is depicted in Figure 1. Toxic heavy metals such as lead, cadmium, and mercury are being studied in great detail. The increasing use of fossil fuels for transportation, and the trend among various industries and temperature-controlled commercial and residential buildings, have led to an

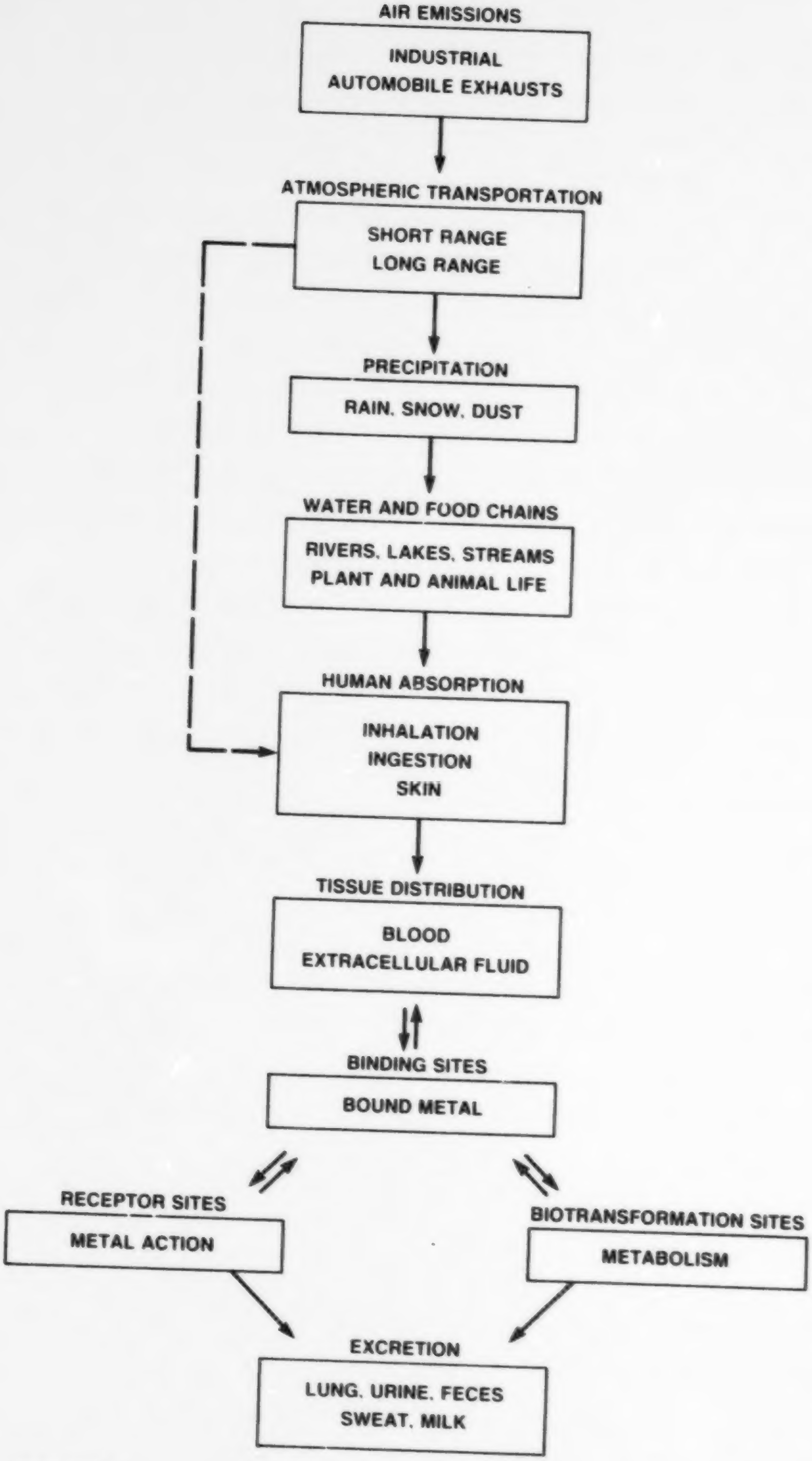
AIR EMISSIONS
INDUSTRIAL
AUTOMOBILE EXHAUSTS
ATMOSPHERIC TRANSPORTATION
SHORT RANGE
LONG RANGE
PRECIPITATION
RAIN, SNOW, DUST
WATER AND FOOD CHAINS
RIVERS, LAKES, STREAMS
PLANT AND ANIMAL LIFE
HUMAN ABSORPTION
INHALATION
INGESTION
SKIN
TISSUE DISTRIBUTION
BLOOD
EXTRACELLULAR FLUID
BINDING SITES
BOUND METAL
RECEPTOR SITES
METAL ACTION
BIOTRANSFORMATION SITES
METABOLISM
EXCRETION
LUNG, URINE, FECES
SWEAT, MILK

FIGURE 1 ENVIRONMENTAL AND HUMAN PATHWAYS OF POLLUTANTS

ever increasing and undesirable release of trace elements into the atmosphere. This is further compounded by emissions from metal smelters, waste incinerators, and petrochemical plants. In particular, sulphur has recently received a significant amount of attention since it is one of the main precursors of acid precipitation. However, the "co-contaminants" of acid rain and snow are also considered important in this laboratory and in a few others. Elements such as vanadium, manganese, mercury, lead, nickel, copper, zinc, arsenic, cadmium, and selenium, which can be emitted together with sulphur, are all potentially toxic even at quite low concentrations. Furthermore, their respective synergistic and antagonistic toxicological properties indicate a need for multi-elemental determination of a group of such pollutants in each sample.

Ratios of pairs and groups and specific emitted elements can act as "fingerprints" of certain dominant sources of pollution: certain lead/bromine and lead/chlorine ratios suggest automobile sources (Paciga, Roberts and Jervis, 1975). Other more recent "markers" include the ratios of manganese/sulphate ions (Lindberg, 1981) and manganese/vanadium ions (Rahn, 1981).

The initiation of environmental studies can be described in the following four supportive and interactive topics:

1. Evaluation of Priorities
    - toxicological implications
    - urgency of toxin
    - availability of analytical methods
2. Assessment of Trends, Concentrations, and Distributions
3. Effects on Biological Systems
4. Government Officials

A crude but effective Venn diagram showing the interdisciplinary nature of environmental monitoring is shown in Figure 2. Often studies have been initiated in which the toxicologist, environmentalist and analytical scientist have not always been aware of or seen the significance of each other's work. Certain new analytical techniques pushed to their detection limits have often been considered too imprecise, inaccurate, or time consuming by the environmtnal scientist or toxicologist. On the other hand, new methods are often not readily accepted as being useful and reliable. Nuclear analytical techniques are prime examples.

Analyses of wet precipitation (rainfall and snow) and dry deposition are important indicators of trace elemental atmospheric pollution. The process of removal by

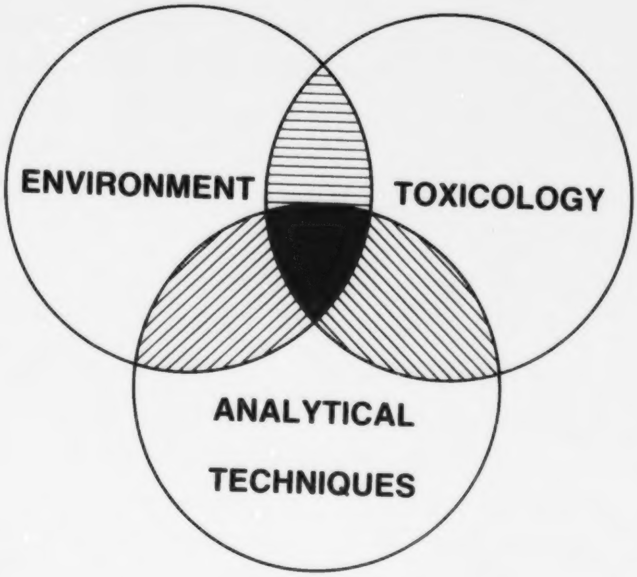

FIGURE 2 VENN DIAGRAM SHOWING THE INTERDISCIPLINARY NATURE OF ENVIRONMENTAL MONITORING

precipitation of airborne matter from the atmosphere, both soluble and particulate, can be distinguished as:

1. Washout - scavenging of particles by rain or snow below the cloud base.
2. Rainout or snowout - a process in which particulates become incorporated into or attached to cloud droplets which grow to raindrops or snow crystals.
3. Sedimentation - particles with dimensions greater than 10 - 20 μm fall to earth.

Furthermore, snowflakes fall more slowly than raindrops or equal mass and sweep out a larger area, resulting in a greater exposure to pollutants. Snow, therefore, can be a better indicator of atmospheric components than rain.

Reliable methods are needed to analyze and evaluate the usually low concentrations of trace elements in precipitation to permit a tracing of the fate of the pollutants in the atmosphere and to evaluate the role of rain and snow in the movement of elements through the environment. A knowledge of trace element concentrations can aid in correlating morbidity and mortality rates, setting toxicological standards, and initiating epidemiological studies.

Thus, we have an interest in doing some environmental monitoring for various reasons. We must determine what the priorities are. We must first evaluate them. We cannot do mindless monitoring. We must determine the toxicological implications. If there are no toxicological implications, with the lack of resources for research, you will not study that particular area of interest. We must deal with the urgency of the toxins. Certainly it would be nice from a purely academic and research point of view to study everything all the time. The field must be narrowed. For instance, lead and snow and dioxin are most likely of very high priority.

First, you must consider the availability of analytical methods. As I said before, there are certain methods which are often used which are either too time consuming or have been pushed so far to their detection limits that if you have a plus or minus 50 or 60 percent attached to it, the results are usually taken with a grain of salt.

Environmental monitoring must assess trends, concentrations, and the eventual distribution of the contaminants.

Something that hasn't been done too much is monitoring the effects on the biological systems. Mr. Vanier said yesterday that there are some ongoing studies to understand the effect of snow dumping into the St. Lawrence River and that they are starting to do some environmental monitoring.

Finally, and something that also is overlooked, you do environmental monitoring for governmental controls. The government is not going to introduce any new type of legislation, it's not going to give any funding unless certain pilot projects are started and certain data is presented in good format to show that there is a need. So for me to come here and ring the bell saying that there is a particular type of urgency in something doesn't mean that I will be able to obtain a fifty thousand dollar grant. I would have to have people who have some initiative and really present their case very well in order that they can get the money.

I don't want to bombard you with all the analytical techniques, but I want to mention some of the things which I have found in the Montreal snow. According to the U.S. Environmental Protection Agency, snow and rain samples should be filtered. It is very important to distinguish between what is called the soluble portion and what the insoluble part is. For the most part, 80 percent of the pollutants in the insoluble part or the particulate part are nontoxic and probably will remain nontoxic with the exception of certain elements which I will discuss later.

The action is with the soluble part. Recently there have been some people who have proposed that if you present any data on snow or rain, the data should not be accepted if it has not been filtered through something like a 0.4 μm pore size. This gives you a very good indication, an early indication of the bioavailability of these types of metals, sulphurs, and things of that nature.

I will briefly describe one snow sample that was collected around the island of Montréal at the beginning of February 1979 at approximately 30 places. There was a spectrum of results. There was:

sodium
aluminum
phosphorus
potassium
titanium
curium
nickel
zinc
bromine
rubidium
cadmium
magnesium
silicon
sulphur
calcium
vanadium
iridium
copper
lead
selenium
scandium

There is a whole soup of these metals and heavy metals which come down with the acid snow. Of course there are also some photochemical oxidants and synthetic organic compounds.

Next we will consider particulate matter, that portion of the snow which has been filtered out. Once again, all the elements are there starting from sodium to copper and zinc and all the refractory elements, again sulphur and elements like silicon which for the most part come from erosion and wind erosion and from the earth's crust.

A technique which I have been using is called neutron activation analysis. Again, I won't go into the techniques of this. The soluble portion shows other elements that can easily be determined such as iridium. Now most of these elements are in the range of parts per billion, but even at these low concentrations they can have very severe toxic effects.

A case in point: the minute quantities of aluminum which are released through acidification of lakes have absolutely wiped out many species of fish. We also have identified elements like bromine, iodine, chlorine, along with sodium, calcium, manganese, and also vanadium.

I want to spend about one minute on the techniques. The Ministry of the Environment has been using a new technique called ICPAES or inductively-coupled plasma automatic emission spectroscope which has been out on the market for about four or five years. The beauty of this particular technique is that it is capable of determining upwards to 30 elements in one fell swoop. I mention this for a simple reason. Probably this will be the base technique for at least the next 10 to 15 years for anything to do with rain or snow. This particular machine costs anywhere between $70 000 to about $200 000 plus one full-time technician, but the amount of information you can obtain is phenomenal. You probably could take a snow sample at nine o'clock in the morning and by something like 10:30 a.m. you may have analyzed 40 to 50 samples for at least 30 elements. Mainly, this deals with the soluble portion. There are only about three or four such black boxes available. The National Research Council received one and certain universities. I envision that sometime within the next few years there will be many institutions and also government laboratories that will have this technique.

Now for some environmental interpretations which I think are the crux of this talk. Let me mention one thing which I have said before about the percentage of the soluble part as compared to the insoluble part. I have given you a list of elements pertaining to the snow in the Montréal region. However, these elements can easily be found in many other types of snow from other urban areas. The soluble average concentration from about 30 sample sites showed sulphur with about 1 500 ppb, being 80 to 90 percent in soluble form. Other elements of interest were found, such as cadmium with an average concentration of 13 ppb, all in soluble form. Certainly this is of major concern because if you keep on dumping snow and if municipalities upstream keep dumping snow and if you happen to be situated in a region where the concentrations are pretty high, most of it will be in soluble form and there will be a rather immediate environmental impact, meaning in this case within one, two or three years as compared to something from 10 to 15 years down the road.

Other elements that are also in soluble form are things like nickel, 77%; copper, 83%; and zinc, 77%. These percentages should not be taken as absolute values as they will change from area to area.

Again, it is rather unfortunate that some of these elements, which are potentially toxic and can get into the receiving waters, are also the ones that are the most soluble. I do have one discrepancy, lead. Most people have been reporting that the lead found was mainly in particulate form. For some reason, I have found quite the opposite, that the lead was mostly in soluble form. Let us consider a very rough estimation of the total annual trace element deposition, both wet and dry deposition. I am talking about the soluble portion. I have converted deposition into milligrams per square metre per year and the insoluble particulate matter also in milligrams per square metre per year. Again, there are many elements, and some people may not consider the results as being of a very high magnitude fcr lead, cadmium, zinc, copper, and nickel. These metals are considered by environmental scientists, by certainly quite a few agriculturalists, or by people studying receiving waters, as very high. So this comes in year in and year out and after a while your receiving water becomes polluted when there isn't enough of a flow to provide dilution, or else what is of a more immediate concern, is the effect if you dump the snow on land.

It is rather well-documented now that in many places in Europe the agricultural land is getting scarce and the same situation is now appearing in southern Ontario and also in parts of Québec where the land itself is becoming polluted and you have heavy metal uptake into the agricultural crops. Thus, any type of snow disposal, at least from my perspective, definitely should not be on prime agricultural land. Such land is far too valuable to waste on snow dumping. It is much better to keep it clean and have good food.

When we compare values from trace element content in distributed water across Canada and the levels found in the Montréal snow, we find that cadmium was less than 0.01 ppb; chromium, 2 ppb; copper was 2 ppb; lead was less than 1 ppb; and zinc was approximately 10 ppb. As of now, all the average concentrations are well below the limits set by the Canadian government health organization as well as those set by the U.S. Environmental Protection Agency. The average concentration figures for Canadian waters comes from an in-depth study done by three scientists of the Department of National Health and Welfare out of Ottawa. They looked at over 70 municipalities across Canada and these are some of the average concentrations that they obtained for drinking waters. As the pollution becomes greater, and more snow is dumped into receiving waters, perhaps in the near future snow disposal will add to the concentrations of the receiving waters, and affect the health and welfare of the people drinking the water.

But let me reiterate at this particular point, it does not appear that snow disposal in the last few years has had any significant affect on the pollution of drinking water in Canada.

One of the last things that I want to talk about is what is considered an enrichment factor. I have given you a whole list of elements and all types of concentrations and one of the first questions that should come up is, "So what?" Maybe all these elements have been around for the last million years. How do we know that what you are talking about is of any real significance or environmental value? Back in 1973, two very well-known people, Gordon and Zolar, from the University of Washingon, proposed to have something for aerosols called an enrichment factor. Basically, an enrichment factor is just a ratio of the element of interest in the atmosphere or rain or in the aerosol over a normalizing element, all divided by those same two elements in the earth's crust. Ideally, if this ratio is one or very close to one, or somewhere between one and ten, this would indicate that this element most probably arises from natural sources; wind erosion, entrainment of soil in the atmosphere, and things of that nature, should not be a major concern. I won't go into a lot of detail as to what would be considered as an ideal normalizing element, but some of the ones that have been used in the past have included aluminum, iron, scandium, and sodium. For the most part, people use aluminum. Aluminum has been normalized to one; some of the elements that are not of major concern in a soluble portion may be vanadium, iron, cobalt, also, rabidium and strontium. They do not have very high enrichment factors and they should not be of too much concern. However, some of the other elements have extremely high enrichment factors - like lead, 3 000; cadium with a staggering 220 000; and including some toxic heavy elements of copper, zinc, selenium, bromine, all with factors ranging from 1 300 to 15 000. Of course, chlorine has an enrichment factor of 30 000. One would expect that because of all the salt that is dropped on the road.

There is mathematical proof that chlorine does not come from the sky in a natural way. Sulphur has an enrichment factor of, I think about 7 000. So you can immediately, by looking at a chart, see the elements which are of major concern and you can begin to set your priorities as to what elements should be studied in the most detail and when to begin some serious environmental monitoring.

On the other hand, as I said, particulate matter has very low enrichment factors with the exception of a few elements. Most are very close to one, even sulphur in the particulate state is not all that high, 60 to 62. The noted exceptions are bromine, 4 500; antimony, 330. Antimony can actually come from tires. The erosion of millions upon millions of tires or else the wearing-down of these tires often produces many fine particulates which become entrained in the snow as does zinc.

The National Academy of Sciences in Washington, D.C., made a study of the tire industry and the effect of metals and trace metals that come from tires and how the elements become entrained in the various ecological systems. Lead has an enrichment factor of 90, but by and large the particulate matter is not of major consequence and can probably be dealt with.

Now, if the particulate matter lies in an acidic environment where the pH is 3.5, there may be a time when some of this particulate matter may start to dissolve.

Unfortunately, there have been no studies done of this since the immediate concern is the soluble portion of snow.

For comparison, let's compare an enrichment factor in snow to an enrichment factor in coal. Coal is a common combustion fuel. Many of the elements enriching coal also tend to enrich urban snow: cadmium, sulphur, bromine, chlorine, lead, zinc, nickel, and copper. They tend to be found in the Montréal snow. Conversely, the elements which do not enrich coal, do not tend to enrich either the soluble or the particulate portions of the snow, which gets us back to what we were talking about yesterday. Some of the main problems of snow pollution are the emission sources such as fuel burning, gasoline, and things of that nature.

From my own personal point of view, one of the directions we should take is to reduce emissions. We will have lesser problems in dealing with snow. But this, of course, is more political than environmental.

Metals are not the only thing in snow. In some work which was published in 1979, data was given about polyaromatic hydrocarbons, pesticides, and metals in Bavarian snow. I am not a pesticides man. I don't have a very in-depth feeling about most of their findings. Just from reading the paper, however, I learned that some of the contaminants found are considered high and their levels are also considered to be toxic.

There has been a lot of work done on the emissions from pesticides in agricultural lands and certainly National Health and Welfare Canada has been doing a lot of the research to make certain that things don't really get into the food chain at all. But it seems that there is an approaching serious problem with entrained pesticides and hydrocarbons. Possibly this are will prove to be more toxic than any trace metals because it doesn't take a lot of such material. Just witness the small amounts present before fish in Lake Ontario became contaminated. Most of this material is parts per trillion which may be a little hard to understand, but it doesn't take a lot of it to pollute an environment.

In conclusion, at present I would not consider that all elements pose an immediate problem, but certainly there should be additional research done so that perhaps 10 years down the line we don't say we have made a mistake and we should have done this 10 years ago. I wish the Canadian governments and the various provincial governments would be more in tune with many of the European countries which have spent a lot of time and effort trying to identify pollutants in snow.

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QUESTIONS AND ANSWERS

Question: My children eat snow. I guess all kids have always eaten snow. I don't know if I should be worried or not. What is the difference between my children eating snow and drinking the runoff into the river that has the same contaminant level as in the City of Montréal water? We are talking parts per trillion.

Response: There has been a study in the United States on "inner city" kids eating snow, the ones that live next to the traffic and roadways. There has been some concern because the concentrations are not a few parts per billion, they range from 1 to 4 000 parts per billion. It doesn't take a lot of lead or soluble lead in your blood before you have the onset of learning disabilities and other types of nasties and this has already been documented. This was part of a major lead program for inner city kids who are eating lead from paint off the walls which were sort of falling apart in the inner cities and children eating snow almost on a daily basis. The study was conducted in Chicago and also in the United States. Now I don't know how much snow your kids really eat, but all children eat a little.

Question: I appreciated your comments about doing something about snow disposal and disposal sites but is it really a large problem? After all the road surface is only a small portion of an area in a city. The rooftops, for instance, gather snow. The snow melts and gets into the storm drain system and possibly into the sanitary system depending on how the roof drains are connected and that also has a bearing. The focus seems to be on snow disposal sites and snow disposal off the roadways. Naturally we add salt to it and that's a concern and I think we ought to do something about that aspect of it. All of these other trace elements; what about these other factors? Don't they all get into the watershed, probably to a greater extent than they do from a disposal site?

Response: This is part of the whole problem of the actual contaminated snow coming down. I think that we should have a handle on the total problem. We need to have an overall idea of what the total loading would be from a certain type of suburb or environment. Now, there have been some people saying here that if it gets into the rivers, either in the

St. Lawrence River or the Ottawa River, it is diluted. They say the flow is 8 000 m^3/s or something of that effect and that there is no problem. On the other hand, I still don't think we should blindly go into it and not have a handle on it because things may get worse and it is better to be a little bit on the safe side than on the sorry side. Unfortunately, there have been no environmental studies at all on this in Canada. I will be waiting for the report from the Montreal study. It would be interesting to find out in a couple of years if there has been any heavy metal uptake by the fish or other fauna.

Concerning the previous questioner's point that the bulk of the pollution that comes from the transport of just cars and trucks and so on falls within, let us say, a few hundred feet of a major thoroughfare and it is the traffic in the downtown core that produces urban pollution which is then deposited on the snow. It is snow in those particular areas that is of prime concern. In the residential areas it is not as much a concern but I think there may be some value in streaming the snow from two different sources and treating one with perhaps a bit greater care than another.

Question: You mentioned in your talks that you had tested for soluble heavy metals. What was it soluble in?

Response: I consider soluble that which has been prescribed by the U.S. EPA, that which is filtered through a very small pore size.

Question: What is the pH of snowmelt?

Response: Usually the pH of must of urban snow at the end of the season tends to be on the high side. Initially, I think it would be around 4 or 5, but it is usually over 6. I was told later that the increase has to do with snow just aging and the deposit of dust. Calcium deposited on it will neutralize the pH findings over the season, so a real test of what the pH of a snow would be is to catch it by event basis. My samples were collected at the end of the season.

Question: Your lead findings in the drinking water versus the Montréal snow were approximately 1 to 27. 27 parts per billion in Montréal snow and drinking water less than 1?

Response: Yes.

Question: Are we to assume that the lead that is soluble in the snow is getting into the river and becoming insoluble because it is binding to particulates or does it change in pH or does anybody know?

Response: I certainly don't know and I have never seen any papers on that either. I guess what I was trying to indicate is that the concentrations in the snow are much higher than any of the concentrations found in the drinking water which would lend credibility to the position that the snow can be dumped in receiving waters in order that it become diluted. That is just one possible hypothesis.

Statement: I am concerned that we are becoming somewhat preoccupied with some of the toxic heavy metal substances, which in my view have very little to do with snow. They are going to be there anyway. These same materials are being discharged, collected out of the atmosphere with mechanisms that have been described, whether it is being scavenged out with snow or not being brought out with the snow. It would seem to me that we are in great danger of getting hung up on something which is totally independent of snowfall. We are really talking about snow disposal, the micropollutant problem. We are dragging a red herring across the track. When you talk about snow you know that the things that you add to snow simply because it is snow, like sodium chloride, calcium chloride, and sometimes sand, perhaps in the future calcium and magnesium additives, are going to be added and those are unique to the disposal problem.

The whole question of lead, cadmium, zinc, and atmospheric transport are things to do with any kind of precipitation. They are sitting out on the streets right now in June in Montréal, so if the road is washed before it is swept, you are going to have lead and other contaminants in the storm drains and they are going to go into the river. I would consider that to be the subject of another workshop which has to do with atmospheric transport of heavy metal. I am not certain that it really has to do with snow disposal. The only relation that snow disposal has to it is perhaps that it traps this material and when you collect it and put it on the bank of the river or you throw it into the river you have now discharged it at one point at one time and you perhaps have concentrated it. On the other hand, you can say that snow is a means of preventing this material from getting into the river because when you take the snow which has trapped this material and put it onto the land, and we've been talking about the possibility of land absorption of this material, maybe snow, in fact, is helping to prevent contaminants from getting into the river.

I am a bit afraid that if we are not very careful, we can get totally preoccupied with what appears to be a very serious problem, but is really quite independent of the snow exercise.

Response: I would agree with you certainly on particular aspects but I think it just comes down to taking a lot of snow and putting it into one, two, or maybe three sites. Now if the snow was evenly distributed or gotten rid of throughout the snow year along with regular street cleaning or something like that, I don't think it would be a major concern. The fact that you take so much of the snow and put it onto one or two places may be a possible concern and I think that should be looked into.

Statement: I think this adds credibility to the idea of direct disposal over the course of the winter.

Response: Yes. First of all, you're disposing into a river in which the metabolism of the aquatic life is at its dormant stage over a period of four or five months. Secondly, the instantaneous high concentrations occur at the beginning of the melt. Perhaps by disposing of urban snow in land sites and not controlling the runoff, we are in fact sending a soup of pollutants down the river with the spring pressure. Spring is when most fish species' eggs hatch and the reproductive cycle is going on.

I do not know what the fish population is in the St. Lawrence River, but I am certain that with all the snow that actually comes from disposal along with acid precipitation, the fish are suffering. I agree that more control on how snow is dumped and the timing of snow disposal should reduce the environmental impact as much as possible.

Question: Are there sampling methods to reduce the enrichment of snow contaminants by ground features?

Response: There are many ways of refining the sampling of snow. You could collect it on an event-by-event basis or you can do what a lot of people in the Scandanavian countries do and that is look at the profile of the snow at the end of the season. Atmospheric fallout is a common problem. It is everywhere. It has nothing to do with snow disposal as was said before. What is interesting is the difference between the snow that stays on the road as compared to its original condition.

Question: To put the problem into sort of a perspective, I wonder if you have information as to the proportion of trace elements load on an annual precipitation?

Response: I do not have that information with me, but such numbers have been developed.

REPORT OF THE LAND AND QUARRIES PANEL

Al Maurer, Chairperson
Mervyn Perkins, Recorder

A number of specific environmental factors must be considered when snow disposal to land or quarries is evaluated. Groundwater quality, and land use and development, are of particular concern. Melt water must be released from a site to surface waters and aquifers in a manner that will minimize pollution. A prime consideration is the adjacent land use and proximity of the site to residential developments. Noise, vehicle traffic, and visual impact are further considerations. A further concern is the possible alternative uses for the site, both during and after the snow season.

Mitigation of erosion and sedimentation potential, as well as a recognition of the impact of prevailing winds and soil types on vegetation and wildlife, must be considered during site evaluation.

Current disposal practices are perceived as potentially damaging to surface and groundwater supply. In addition, disposal sites, by taking land away from potential development for other uses, could be harmful to the site because of contamination of soil and vegetation, and depreciation of adjacent property value due to noise and traffic congestion. Existing wetlands are also considered vulnerable to the adverse effects of snow disposal.

Although the real and potential environmental impacts of snow disposal to land and quarries have been recognized and have been of concern to regulatory and operating agencies, the panel was unable to identify relevant research currently being conducted which would assist agencies in mitigating adverse environmental impacts. The panel was also unaware of commitment by any level of government to fund research which it believes is needed. Specific research needs identified as of particular interest include:

1. Movement of leachate through acquifers.
2. Impact of urban snow melt on environmentally sensitive areas.
3. Impact of acid precipitation on the leaching of heavy metals, particularly lead.

The panel suggests that public agencies should provide for monitoring programs to allow evaluation of the impact on the environment. Monitoring to be carried out should include, but not be limited to, the following:

1. Receiving stream quality prior to initiation of dumping during and after snow season.

2. Quality of melt water for dissolved chemicals and suspended solids.
3. Snow quality for solids.
4. Downstream aquifers for water quality for three years.
5. Rate of flow of receiving stream with correlation to the volume of snowmelt water discharged.
6. Noise level at adjacent land before and during disposal site use.
7. Soil levels of chlorides and heavy metals before and after use.
8. Extent of illegal dumping by private parties.

Criteria for site selection as developed by the Province of Ontario (*Guidelines for Snow Disposal and Deicing Operations in Ontario*) were considered satisfactory and usable with the exception of paragraphs one and two on page 6. It appears very desirable that receiving waters be adjacent to the site and that the soil be relatively impermeable.

The panel members emphasized that the site should be affordable, should be operated quietly and efficiently, and have sufficient area.

During the operation of a snow disposal site the panel urges that all protection devices be maintained and that all monitoring arrangements be strictly adhered to with permanent records kept. Upon completion of the operation or at least every five years or so, contaminated soil, if such exists, should be removed using appropriate practices or guidelines depending upon the type and degree of contamination.

In addition, when quarries are used, the extent of exfiltration should be ascertained and provision for pumping of snowmelt into the receiving stream provided.

The principal constraints upon public agencies as they attempt to minimize the environmental impact are from three sources. First, political realities, legal problems, and site-specific economics are major influences. The ability to provide long-term solutions and to meet the needs of the various public sector interests is an additional subset of this area of constraint.

The unpredictability of snow events as well as the natural mobility of pollutants represent major inhibiting constraints upon those responsible for snow disposal operations.

The third major area is the quandry of public agencies as they develop standards for the use of deicing chemicals. The economics of providing a high degree of mobility for the public as balanced by the adverse impact of chlorides, for which there are no adequate guidelines for evaluating their impact, leaves the public agency in a "no win" situation. Public agencies traditionally are challenged to meet a "level of service." In this case, the level of service is poorly defined.

As a means of overcoming the problems associated with the disposal of snow to land and quarries, the panel recommends that a task force involving the three levels of government be formed to identify and allocate responsibility for the research needed. Clearly, identification as to the level of government responsible for each particular area must be agreed upon. Major research should be undertaken in areas such as the need of snowmelt treatment, movement of leachates through aquifers, impact of snowmelt on environmentally sensitive areas, and the role of acid precipitation in combination with lead. Specific research should be undertaken into ionic exchange and absorption in melt water and storm water; pathway bioaccumulation of lead, sodium, chlorides and other microcontaminants; alternative strategies to minimize the use of sodium chloride; feasibility of disposing of contaminated and hazardous soil; education of the public, politicians, and media; design criteria for snow disposal sites; and the use of floodplains and wetlands for snow disposal sites.

The panel developed the following recommendations for selecting and operating land and quarry disposal sites in addition to those provided by the Province of Ontario:

1. The disposal site must be near the source of the snow to be disposed of.
2. The site must be accessible to a truck route system or some other heavy duty road not close to residential areas.
3. Control of noise should be given high priority inasmuch as much work will be done at night. The site should be as far away from residences as possible.
4. If at all possible, the site should have an alternative use in off seasons, but only by the public agency due to its possible contamination.
5. The site should be screened and enclosed. Trees should be placed in such a manner that piles of snow will not be shaded.
6. Soil should be impermeable at about the one metre depth to avoid discharge into nearby aquifers and to enable controlled discharge into an adjacent receiving stream. The rate of discharge, quality of discharge, and the depth of the filter layer should be subject to research.
7. The area should lend itself to the monitoring program previously mentioned.
8. The site should lend itself to ease of cleanup and change of filter layers.

In summary, the panel emphasized that in the successful selection and operation of a land or quarry site a number of factors must be taken into consideration. A prime concern must be the economic feasibility of the site. Is it functional, large enough to serve the area within a reasonable distance? In addition to economical feasibility, environmental factors such as melt water quality, impact on vegetation and soil, noise and health, must be taken into consideration. A number of other environmental factors should also be considered. Additional research will be required before public agencies are able to properly plan their operations to minimize environmental degradation.

REPORT OF THE RECEIVING WATER PANEL

Donald B. Dutton, Chairperson
John Drake, Recorder

The panel considered the practice of disposal of urban snow directly to receiving waters. When public agencies consider such means of disposal, some of the environmental factors that must be evaluated include the following:

1. The mixing or dispersal capabilities of the receiving waters must be determined. In rivers there should be winter flow sufficient to carry the snow and ice away from the site without creating a dam of snow and ice. In lakes, shallow bays should not be considered suitable.
2. The levels of contaminants in the receiving water should be low enough that the increased load presented will not cause standards, if and when standards are established, to be exceeded.
3. Site conditions should preclude the possibility of erosion, local flooding, or frazzle ice formation due to snow disposal.
4. Addition of the snow and ice should not adversely affect the receiving waters' biota, or plant and fish population.
5. The impact of the contaminants in the snow on aquifers fed by the receiving waters should be considered.

The levels of the three major categories of contaminants in urban snow and ice are determined by separate influences, as follows:

1. De-icing chemicals and sand are controlled by local agencies and established management policies.
2. Other contaminants present in the snow are derived from the surrounding environment and scavenged from the air.
3. Urban litter and solid wastes may be picked up during snow collection by the local agency's work crew.

Levels of the first group of contaminants may be established by the agency in setting its level of service to the public. Group two contaminants often result directly or indirectly from regional, national, or international policies. The local public works agency can minimize the third group by appropriately timing snow removal operations.

Other site-specific considerations judged by the panel to be very important include site economics and social impact. Transportation costs, i.e., distance to the site from the urban area, and site development costs, including acquisition as well as provision and operation of protective works, are the primary economic considerations. The immediate and the cumulative effects on upstream and downstream users such as downstream municipal water intakes or upstream snow dump operations must be considered as well as the aesthetics of the site, both of which are important social factors to be evaluated to reduce adverse public reaction.

In reviewing the impact of current disposal practices on the environment, the panel concluded that:

1. Documented effects are extremely site-specific. These should be regarded as potentially, but not necessarily, important for other sites.
2. Heavy metals have been found to accumulate in bottom sediments of receiving waters (as referenced by Niblett).
3. Suspended sediment from abrasives can settle and blanket the bottom of receiving waters, and interfere with bottom-dwelling flora, fauna, and fish spawn.
4. Where road salt is used extensively, an increase in chloride concentration in smaller bodies of receiving waters has been detected.
5. It appears that the loading of contaminants from direct deposition of snow into waters is less than that from sewage treatment plants and, in particular, from storm runoff generated from snow in situ by melting agents.

Some suspected or possible problems have not been documented, e.g.,

1. Organic contaminants may be chlorinated in downstream water supplies and generate toxic compounds.
2. Trace metals and organics, e.g., pesticides, may have a deleterious effect on the biological quality of the receiving waters.
3. Odour and taste problems may arise in downstream water supplies.

The following conclusions regarding research needs were reached:

1. There appears to be no specific "marker" substance than can be used to define uniquely the impact of snow disposal compared to, for example, storm sewer runoff. There is some suggestion that lead may be used for this purpose if other point sources of it are absent from the area under consideration. Establishment of a "marker" would facilitate problem identification.
2. There has been little research into the effects of snow disposal on the flora and fauna of receiving waters. However, there is a possibility that contaminant-loading

in winter may be less of a problem than summer loading because of the lower biological activity.

3. There has been some research into the effects of heavy metals, but the effect of direct loading through snow disposal is uncertain. Reliable information on the toxicological impact of the concentrations found in snow is not available and should be established.
4. Much of the research on acid precipitation (largely rainfall) may be applicable to the disposal of snow. A detailed literature review is needed.

Two significant studies of the impact of snow disposal into receiving waters are underway, one by the City of Montréal, with a report due in 1985, and one by City of Edmonton, with a report due 1986-87. These reports, when available, will be very helpful.

Monitoring practices suggested for snow disposal sites by the panel include:

1. comprehensive, ongoing sampling of snow contaminants to determine instantaneous and daily contaminant loads;
2. measurement of the rate of snow melt and the fluctuation in receiving waters flow;
3. sampling of condition of receiving waters both above and below point of disposal; and,
4. prior to establishment of the site, frequent sampling of the receiving waters over one year to provide a baseline.

Desirable site selection and close-out criteria were suggested as follows:

1. **Selection**

   a) The impact of a site on residents should be minimal. Among the criteria are:
      - minimization of noise from trucking and disposal operations,
      - minimization of disturbance due to traffic at the site,
      - preservation of water and air quality in the immediate vicinity of the site, and
      - provision for the aesthetic (visual) impact of the site and deposited snow.

   b) The site should be easily accessible to major traffic arteries and collection zones to minimize costs and traffic disruption.

   c) The site should be secure to prevent unauthorized dumping of snow or other materials. This should minimize the problem of trash and garbage accumulation at the site.

d) The site should not present a public safety hazard from unauthorized use, e.g., skiing or tobogganing.

e) The site should, as far as possible, be permanent. This allows a greater investment in site selection and impact analysis. It also allows greater investment in provisions such as tree screens.

f) Costs for site acquisition and operation, and for hauling to the site are clearly of major importance.

2. **Close-out**

a) The site should be returned to its original or better state. This may involve the removal of heavily contaminated bottom sediments from the receiving waters.

b) Subsequent uses of the disposal site should be restricted to those compatible with any possible residual contamination.

The panel concluded that good practice in snow disposal includes minimizing the quantity of contaminants in the snow disposed of. Consequently, it is suggested that:

1. Snow pickup should be controlled to eliminate inadvertent collection of garbage and other wastes. This may require scheduling of snow removal behind garbage pickup, public education to ensure that garbage is not incorporated into snow, or manual clearance of garbage from snow along streets.
2. Snow should be loosely packed in trucks, perhaps by blowers rather than loaders, to reduce the size of individual snow masses dumped into receiving waters. This hastens the melting of snow in the waters and reduces the chance of erosion and downstream jamming.
3. The dumping rate should be such that the assimilative capacity of the receiving waters is not exceeded. This may require temporary storage of snow alongside the disposal site.
4. Some control on haulers may be necessary to eliminate extra wastes from practices such as oiling of truck beds to facilitate unloading. If nonmunicipal snow is disposed of, no wastes must be allowed in the loads.
5. A modeling approach based on a worst-case analysis might be developed to determine optimum disposal rates given values of receiving water quality and flow, and snow volumes and contaminant concentrations.

The principal constaints upon achieving minimal environmental impact from snow disposal operations were judged to be:

1. **Economic Constraints**

   a) Timing of snow loading. Snow loaded within 48 hours has been shown to have a minimum contaminant level. Such procedures may not be practical due to work force economics, and/or budget restrictions.

   b) Haul costs. Site locations may be guided by politically determined cost limitations.

   c) Loading methods. Snow loaded by blowers contains less litter and solid wastes than that picked up by front-end loaders. Practical considerations may preclude this method.

   d) The type of de-icing chemical used and the rate of application may be constrained by cost and/or public acceptance. Some chemicals other than salt have less environmental impact but are much more costly. Reduction of salting rates would reduce environmental problems but the end results may be economically devastating to the public and private sectors.

2. **Contaminant Constraints**

   Most environmental contaminants come from emissions from vehicles, heating facilities, and industry. Only provincial and federal governments are able to take action to reduce levels of these emissions.

3. **Environmental Constraints**

   a) The geology and/or hydrology of the site, soil types, slopes, receiving water configuration, etc., may be fixed.

   b) The rate of snow melt cannot be controlled and may require other measures to reduce shock loading.

Priorities for required research which would allow disposal site operators to improve their operations and minimize adverse environmental impacts were suggested as follows:

1. Develop uniform criteria for site monitoring and data evaluation. Monitoring parameters should be ranked to avoid collection of data that would have little significance. Uniform criteria would allow different agencies to provide input to a comprehensive data base.

2. A comparison of pollution effects from land dumping as opposed to receiving water disposal should be conducted to assist in the evaluation of alternatives.
3. Contaminant effects on flora and fauna need evaluation to establish acceptable contaminant levels.
4. To provide alternatives to sodium chloride, other de-icing agents and their use should be studied. However, their effects when combined with existing contaminants should be evaluated to avoid the introduction of new problems.
5. Existing or proposed sites should be studied in relation to local snow and receiving water characteristics to develop a data base to assist in evaluating potential new sites.
6. The effects of slug loading as opposed to controlled discharge to receiving waters should be assessed.
7. Testing to determine the biological availability of toxics and biotesting of snow is needed. In the latter case, procedures must be developed. A modeling technique may be useful in these areas.
8. A cost/benefit study should evaluate whether research on snow disposal would provide an improved return compared to research on the reduction of other environmental contaminants.

In summary, the panel concluded that a senior government mechanism is required to establish standards and to deal with intermunicipal problems which may result from water disposal of snow. Environment Canada should consider taking the lead in the reseach activities which are needed in close cooperation with provincial ministries of environment and local government agencies. Environment Canada should provide standard procedures, prioritize parameters and provide funding for the work.

The panel was concerned that many existing and proposed restrictions on snow disposal which have not been proven necessary by research unduly penalize local agencies and greatly increase their costs.

Considerations on the reduction of salt use must be balanced against the needs for public safety, the movement of goods, and the maintenance of production.

Direct disposal of snow into receiving waters may be acceptable or even preferable to land disposal under certain conditions. These include the factors which have been outlined. Advantages of water disposal include the avoidance of the shock loading of pollutants by the initial melt of snow dumps, and the elimination of dedicated land areas.

Disadvantages include the addition to waterways of solids that would otherwise be retained on land.

The control of contaminants at their source appears much easier and more cost-effective than the control of contaminants loading from snow to receiving waters. This may be particularly true of substances such as lead wich emanate from readily identified and potentially easily controlled sources. Snow additive (melters and abrasives) control can reduce the mass of contaminants to be disposed of. The optimal use of additives and operator training can be of significant benefit. Similarly, rapid pickup of fallen snow can reduce the loading of other contaminants and consequently reduce the problems associated with snow disposal.

Finally, the public must be informed and convinced of the necessity of snow disposal, and of the choices of disposal methods and sites available to a particular public agency.

REPORT OF THE WASTEWATER TREATMENT PLANT PANEL

Henryk Melcer, Chairperson
Richard J. Gietz, Recorder

The panel considered the implications of the treatment of snow and/or snowmelt to the satisfaction of provincial and/or municipal regulatory standards. In this capacity, it is recognized that each wastewater treatment problem must be approached on a site-specific basis and often only a unique solution exists.

In assessing environmental factors that may govern location of sites for disposal of snow and/or snowmelt, it is useful to relate treatment options to snow management alternatives in the following ways:

1. Treatment via wastewater treatment plant (WWTP) and sewer collection system by
    a) direct injection of snow to sanitary sewer,
    b) mechanical melter discharge to sanitary or stormwater sewer,
    c) solar melt runoff from snow dump site into sanitary or stormwater sewer.
2. In general, on-site treatment at land snow disposal site.

The location of sites for snow injection, mechanical melters or land snow dumps in Case 1 is governed by proximity and accessibility to a sewer system consistent with minimizing the public nuisance effect. The location of land snow disposal sites (Case 2) is governed by criteria discussed by the other two panels. A more detailed assessment of the criteria to be evaluated in Case 1 follows.

If direct injection of snow to a sewer is to be considered, any ice or snow particles must be small to negotiate combined sewer overflow regulators, lift station pumps, and WWTP intake pumps. Studies by the City of Montréal, as reported by Mr. Vanier, have shown that the minimum sewer diameter should be two metres and minimum sewage flow rate, two cubic metres per second. Montréal's research also indicates that the maximim fall of snow into a sewer should be seven metres to prevent the formation of ice dams in the sewer. It seems implicit that the rate of snow injection is a function of sewage flow and temperature; that is, if the injected snow is to melt prior to arrival at a combined sewer overflow regulator or pump station, the minimum sewage temperature and flow must be defined. The merit of using the sewer as a conduit for snow instead of truck transportation can only be assessed in terms of an economic evaluation, provided that the design WWTP hydraulic loading is not exceeded. It is also evident that snow management has to take into account multiple injections of snow into the same sewer while preventing snow jams. Finally, direct snow injection should not be considered for stormwater sewers since, during winter months, they are unlikely to have an adequate flow to carry and melt away the snow.

Where the sewer capacity is too small for direct snow injection, mechanical melters could be considered. Their use can, of course, also be contemplated with larger capacity sewers, although this would need to be subjected to an economic evaluation.

Where WWTPs are considered for the ultimate treatment of snow and/or snowmelt, the parameters of interests with respect to performance monitoring include:

- incremental sewage flow rate and temperature monitoring (would require monitoring at different points in the sewer system and at the point of entry to the WWTP);
- incremental grit removal at WWTP (would require historical data as well as amounts of grit removed during snow dumping incidents; where mechanical melters are used, grit will be removed at the melter); and
- size of snow/ice pieces and their density at point of dumping to compute mass loading (if snow injection is practised).

For land snow disposal sites, snowmelt should be monitored for parameters governed by local bylaws if discharge to a sanitary and/or storm sewer is contemplated, or for receiving water guidelines for discharge to receiving waters. Grit will remain at the dump site after all the snow has melted.

The impact of snow and/or snowmelt on WWTPs was thought by the panel to be minimal. However, the change in hydraulic and grit loadings could affect both primary and secondary WWTPs. The decrease in sewage temperature resulting from melted snow will probably impair the performance of a biological treatment plant, especially if nitrification is a requirement. No impact is expected from the presence of salt and it is likely that the salt will pass through the WWTP unchanged. The impact in terms of other conventional parameters, BOD, COD, TSS, NH_3N, and TP is likely to be small but should be assessed. The snow characterization data presented in papers at this workshop (Raviolatti, Malmquist) are inadequate to derive any further conclusions and point to the need for more systematic data collection.

The panel was concerned with the impact of disposal of urban snow and snowmelt into sewers for eventual treatment at wastewater treatment facilities. The panel found there is relatively little research available to establish the impact of disposing of snow through wastewater treatment plants. Quantification of pollutants in snow removed from urban streets has, so far, not indicated unusually high concentrations of parameters conventionally of concern, e.g., BOD, suspended solids, total phosphorus, which could be expected to complicate the treatment process. Some research has identified the species and quantities of trace metals in some areas, although these are very site-specific. Because the treatment process results in a bioconcentration of trace metals in digested sludge, which may be ultimately disposed of on croplands or landfill, the potential impact of increased removal of trace metals should be determined. Toxic organics and hydrocarbons also have not been quantified and could potentially be of concern in wastewater treatment, since these have been shown to be concentrated in roadside snow.

Wastewater treatment plant operation may be affected substantially by the volume of water produced by disposing of snow to sanitary sewers. The potential exists for increased hydraulic loading to impair plant performance, especially where treatment plants are operating at or near capacity. Of importance here is the rate at which snow or melt water is injected into sewers. Injection at periods of low flow of domestic sewage will minimize the hydraulic impact. The rate of injection, however, may be limited by physical constaints dependent on the ability of the sewer line to melt injected snow.

Reductions of sewage temperature caused by melting snow may also adversely affect the biological processes of wastewater treatment, but the impact is largely unknown. To avoid difficulties with operating equipment and sewer blockage, experience in Montréal has shown that injected snow/ice should be melted before it reaches the treatment plant.

The large quantitites of sand and grit in snow may present some problems in treatment plant operation such as increased sludge pumping time and equipment wear, especially if grit removal facilities are inadequate.

There is a need to collect operating data on various sewage treatment plant unit processes during periods of snow disposal to sewers to determine the nature and extent of problems, if there are any.

Where snow is collected on land surface dumps and the melt water is discharged to storm sewers, the above parameters or interests apply, perhaps with the addition of microbiological considerations, such as fecal coliform and fecal streptococcal bacteria. A need exists to characterize further the nature of snowmelt. The volume and pollutant concentrations of melt water may vary considerably because of the variability in melting rates during early spring.

In general, the following research needs have been identified:

1. Establish the state of current research through both a literature review and a review of current practices.
2. Collect data on nature of snow/snowmelt and treatment plant operating characteristics during snow disposal.
3. Collect data on cost of disposal to sanitary sewers and problems of injecting snow/melt water into sanitary sewers.
4. Determine impact of snow on combined sewer overflow regulations in systems served by combined sewers.

The panel believes that water from snow melted by mechanical melters can be received by most sanitary and storm sewers. Because the rate of melting is usually slow compared to the sewer capacity, discharge can be to relatively small sewers. Mechanical melters usually remove grit and most of the particulates contained in the snow, minimizing the impact on treatment plants. However, melting may be economically unattractive.

Where snow/ice is to be injected directly into sanitary sewers, the following are suggested:

1. Minimize pickup of large objects by blowing snow rather than using loaders.
2. To avoid sewer blockages, coordinate dumping sites to avoid injection where capability to melt no longer exists. Mechanical breakup of the snow may be required.

The panel was unable to determine the relative significance of pollutant loadings generated by snow disposal compared to the total annual pollutant loading generated by all other sources. For some parameters further study may reveal that there is unlikely to be a problem either in loadings generated or in impact on the environment. Such "pollutants" may not require any resources for corrective action. Further evaluation of the loadings from snow is required to identify any significant problems and then allocate resources to deal with them. It is expected that because of local conditions and site characteristics, it will be difficult to generalize problems from area to area.

In summary, the panel believes that the economic and environmental benefits of alternative snow management practices should be evaluated to determine the acceptable method of snow disposal.

Where a high quality treated effluent is required, discharge of all snow/snowmelt should be to sanitary sewers, and then, to a treatment plant. Important technical considerations that should be addressed include the in-sewer snow melting rate and grit removal.

Where the environment can assimilate lower quality water, discharge to a treatment plant may not be required. Economic considerations will likely control the method of disposal.

SUMMARY STATEMENT

Roger K. Brown
Commissioner of Works
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Ladies and gentlemen, I would like to take you back to the opening statement by Paul Choquette, of Environment Canada. It was clear that the initiative for this workshop flowed from an interest and a concern expressed by the Federal Minister of the Environment, the Honorable Charles Caccia. From subsequent presentations, it became evident to me that the extent of the snow disposal problem varied considerably between jurisdictions. Solutions to these problems varied even more. The purpose of the workshop was to have experts connected with snow disposal from different disciplines explore the problems and options in order to achieve a consensus on as many points as possible, and to develop a summary of recommended practices.

First, I would like to emphasize an aspect which was alluded to a number of times, but was not really stressed by anyone during this discussion: why snow disposal is necessary in most Canadian urban areas. As our cities have grown larger and more sophisticated, our population has become almost totally dependent on transportation systems based on automobiles, trucks, and buses which operate on streets and highways. The large volume of vehicles is needed to make our economy go which, in turn, makes our economy dependent on them. If you think about it, food, manufactured goods, and services use the roadways in our urban areas, and definitely people move---to work, to recreation, and elsewhere, in the same way. Under these circumstances, the streets and highways must be kept free-flowing and, above all, as safe as possible. Snow removal, in its various forms, is not really an option, it is absolutely essential. Even removal at bus stops and sidewalks is needed in our crowded, busy environment. In Scarborough, winter control, snow and ice control as we know it, is an important item in my budget (about three million dollars), and yet, it is in competition with many other programs---public safety, recreation, and social services. I know a number of you suffer from the same competition that I do.

We are also aware of the high cost of replacing and maintaining the public works infrastructure, as it is called today. These are some of the constraints that we face. We also recognized that snow disposal is a part of our water and land pollution problem. Contaminants are affecting us in many ways from many sources. It is really in this context that we must look at the social, economic, and environmental aspects of snow disposal. One panel suggested a fairly broad definition for environmental concerns and the social and economic aspects are definitely important.

The presentations and panel discussions seem to emphasize climatic and geographic differences, so that a number of approaches to the problems are necessary. For example, I understand that snow disposal is not really necessary in Victoria, B.C. Yet, in other areas, temperature, snowfall, and polluting contaminants will differ dramatically. Across the country there are many variations. Similarly, the topography, soils, and receiving waters also vary across the country. We have heard that Ottawa and Montréal have large flowing rivers passing by, while a city like Sudbury does not, and that can make quite a difference.

It would appear, based on scientific and engineering evidence, that each disposal method and location should be designed on a site-specific basis. That term has been used a number of times here at the workshop.

A number of common threads appeared during the workshop. The environmental contaminants in snow were clearly spelled out, and it was interesting that the findings of Mr. Malmquist, from Sweden, are similar to the Canadian experience. There seems no doubt that accumulation of lead is of major importance, and also, sodium and chloride are significant. We know why these things are present in much of the snow in our urban areas, but the extent of the detrimental and long-lasting effects of these chemicals is far less clear. It is here that further research is required. There seems to be no question about that. Certainly, consolidation of the existing research as it relates to snow disposal would be most helpful. There seems to be a vast amount of information available, but it is not in collected form where it can be reviewed as part of the snow disposal problem. There also seems to be some common agreement relating to the pollution of groundwater, the discharge to surface waters, the use of quarries, and the majority of the operating considerations for disposal sites. The extent of the environmental impacts are relatively unknown, particularly in the long-term. For example, there was one opinion expressed that there appears to be a build-up of contaminants leaching into the ground, and there is little knowledge as to when, if, or how they will be released in the future. Opinions vary as to whether this may happen suddenly, gradually, or may never happen and these raise many questions. It is questions like this that should be answered by further study, before arbitrary and expensive steps are taken in what could be the wrong direction.

Before I go any further, I would like to summarize some of the panels' findings. I do not pretend that I am going to be able to do this perfectly. There was a wealth of information that came out of the panel discussions. The proceedings of this workshop will provide a good source of reference for the future.

Environmental Factors

Each panel had a list of environmental factors which varied depending on its own immediate area of concern. The importance of the factors mentioned will vary and priorities have not necessarily been established at this time. I noticed that one of the factors was biological characteristics of receiving waters and effects on wetlands. These factors are examples of those that should be considered.

Many concerns were expressed about contaminants and how they affect the environment, and yet we cannot evaluate these in positive terms. How much impact and what are the areas in which that impact occurs? A number of their presentations expressed that same concern. We can document and measure it against other things. As to the status of research we seem to be in agreement that there is little to none in this field. Perhaps there is some, as many of the effects of the individual contaminants have, for example, been established. However, there seems to be an almost universal comment that there is a great lack of research information. In fact, some are convinced that in the case of snow disposal there may not be a problem, as it relates to our other environmental problems.

On the subject of monitoring practices at sites, I think we get back to practical considerations. Most of the panels had lists of monitoring procedures that they would recommend. Quite a few of them were common to the three areas that we are looking at. Monitoring is something that probably can be handled very well once you decide what sort of disposal site you are going to be dealing with and the criteria to be used to select, operate, and close-out a disposal site.

Disposal Practices

The three panels suggested criteria and it would appear that there are many common ideas here. After further consideration, I am sure that others will add other ideas. Again, it seems to depend on the type of site that is being used. Concerning the question as to what constitutes good practice for snow disposal, there is some agreement but it appears that further research is required.

Perhaps it is too early to make hard and fast rules on the question of practices. Certain basic decisions have to be made about methods of disposal, for example. There is much agreement on the principles that should be followed, as expressed by both the panels and the speakers themselves.

I should mention the strong concern shown at this workshop on the subject of the sale of leaded gasoline. I wasn't expecting this, as I had intended to refer to the suggestion that had been made earlier relating to lead in our environment. A consensus exists that the federal government should provide an incentive for the use of unleaded gasoline by lowering the price of unleaded gasoline at the pump. I believe that adopting such a policy should further the reduction of lead emissions. This is the sort of step that could be taken to create rapid and effective changes.

Although there were many different points of view between the participants, which was not unexpected, public interest was certainly foremost and was supported by all concerned at the workshop. The initiative taken by several provinces in Canada in this field is to be commended inasmuch as there is still much to learn and much to be done.

A number of guidelines have been published and some regulations established, but I think is still considerable work to be done to firm these up and obtain support and agreement. Further research is needed, better practices developed, and a recognition of the basic principles that must be applied to the problems. Even if you are looking at problems on site-specific basis, you can use these principles very well.

The matter of general public education should not be overlooked. There should be information and education provided to individuals, the media, and the public at large. It would be best to avoid unilateral decisions without consultation and input from all those having responsibility. The real purpose of snow disposal, namely, the social, economic, and environmental costs and benefits is at the center of this matter. A balance can only be achieved through education and understanding.

This workshop has been a major step towards achieving the needed consensus. I hope it does not stop here, since further meetings are certainly required. The idea of a three-level task force was suggested and I think it is an excellent one. I would strongly urge all government agencies, municipal, provincial, and federal to jointly reach that consensus, and to find answers to the questions that are still outstanding. Our environment and our people deserve nothing less.

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